

ACTA ORTHOPAEDICA SCANDINAVICA

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INVESTIGATION INTO THE CARRYING ABILITY OF PEDICLED BONE GRAFTS DURING TRANSPLANTATION

By

SANDOR MEDGYESI

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It is well known that pedicled grafts are vulnerable and in order to preserve the blood supply it is necessary to handle them by an atraumatic technique. Their transport from the donor site must take place without too much strain upon the pedicle. However, it is not always possible to avoid a certain torsion, flexion or extension of the pedicle when placing it on the recipient site. In dealing with tubed pedicles, rotation flaps and other types of skin flaps, however, there can be ample inspection of the graft so that measures may be taken in time. On the other hand, the pedicled bone grafts cannot of course be inspected. When a poor result manifests itself radiologically or clinically, several weeks or months may have passed.

Good results have previously been obtained by pedicled bone grafts under experimental conditions (3, 5). Under these conditions, however, care is taken not to strain the pedicle, as the sole object has been to ascertain whether these pedicled bone grafts do survive at all, and whether they preserve their osteogenetic activity and healing ability.

To find out what happens to the graft if the pedicle is placed into positions to which it would otherwise be exposed when placed in the recipient site, the following experiment was carried out.

METHOD

The experimental animals were adult rabbits. The grafts were removed from the greater trochanter on both sides using the gluteus med. and part of the rotator muscles as pedicle. The grafts were wrapped in polyethylene foil to avoid ingrowth of blood vessels from the surroundings. The pedicles were exposed in a length of 1 cm. On the right side nothing further was done, as this side served as a control.

In 5 of the rabbits the pedicle on the left side was torquated 180° and fixed in this position. In the next 11 rabbits the grafts were pulled 1 cm distal to the donor site and fixed there. This procedure causes great tension on the pedicle—measured by a spring balance while pulling the graft from the donor site to the recipient site—corresponding to 2 kg. In the last 5 cases the pedicle was flexed so that the sawn surface of the graft faced the side opposite to the original.

The rabbits were killed two weeks after the operation. The specimens were studied histologically after being stained with haematoxylin-eosin. Two of each group of rabbits had microangiography by the method of Spalteholz, filling the abdominal aorta with Prussian blue.

In addition, absorption experiments were done on 4 recently operated rabbits using radioactive sodium $0.2 \mu\text{Ci Na}^{24}$ in 0.1 ml physiological saline was injected subperiosteally into the graft followed by counting with a Geiger-Müller counter. The rate of absorption was taken to represent the circulation in the pedicle. The absorption rate for the normal trochanter was fixed in an experiment on two trochanters.

RESULTS

The torsion was indubitably the most detrimental action. In three grafts all the original osteocytes perished. In two very slight survival could be traced. Nevertheless, the osteogenetic activity in these grafts was surprisingly good (Figure 1). All the control grafts survived and showed relatively little new formed bone (Figure 2). Extension and flexion of the pedicle exerted a considerably less detrimental effect. Total necrosis of the graft was found in only one rabbit after extension and in one after flexion of the pedicle. On the average, half the osteo-

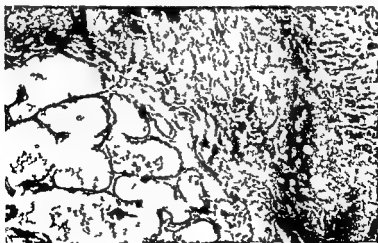
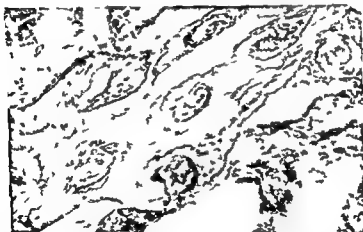


Figure 1 Complete necrosis of the graft. Pronounced subperiosteal callus formation. Torsion of pedicle 180°.



*Figure 2 Graft with intact pedicle Bony tissue alive throughout
The picture is taken in the vicinity of the sawn site*



*Figure 3 Graft with extended pedicle About half the original osteocyte are alive
in this trabecula which is from the middle of the graft Some newformation of bone
at the bottom*

cytes survived in the remaining grafts—in three up to 75 per cent (Figure 3). However in this group too the control grafts showed better survival of the original cells.

Microangiography in a few cases gave a result somewhat divergent from the histological findings, the number of blood vessels that filled with Prussian blue being larger than might be expected according to

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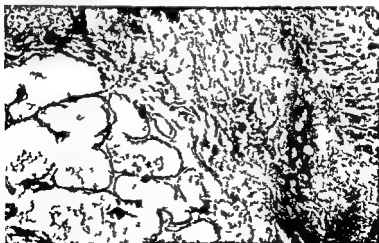


Figure 1 Complete necrosis of the graft. Pronounced subperiosteal callus formation. Torsion of pedicle 180°.

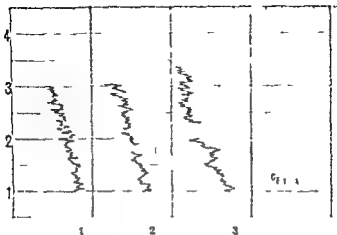


Figure 6 Absorption curves as traced by the Geiger Muller counter The curves start at the bottom The absorption was studied for 20 minutes 1 Normal trochanter 2 Pedicled graft 3 Pedicled graft before and after torsion

torsion caused an extreme reduction in the absorption Extension also entailed marked reduction while flexion in the studied case had no effect (Figure 6)

DISCUSSION

Strainful forced positions of the grafts were deliberately chosen mainly in order to ascertain the utmost carrying ability It is not surprising therefore that *e.g.* a torsion of 180° of a relatively short and thick pedicle entailed primary closure of most veins and arteries in it leading to total necrosis of the bone A somewhat unexpected finding was the pronounced new formation of bone around these grafts It is known however that an osteogenetic factor exists in connexion with a dead bone (1-7) This factor is released by the dying osteocytes and is presumably a protein (2-6) The mechanism of its effect has not been fully clarified It is believed that it takes place through stimulation of capillary proliferation (6) Under the present experimental conditions therefore the grafts have not lost their value as transplantation material in spite of the cell death because of the preserved osteogenetic ability The strong traction did not harm the graft as much as did torsion presumably because the blood vessels are not destroyed before the muscular tissue Incidentally the tense condition always decreases as time goes by because the tissue yields

A radioactive sodium clearance test was performed as is done in

connection with pedicled skin flaps (4) The test was illustrative and the results were on the whole in conformity with the histological findings The method is simple and appears to afford good orientation concerning the circulation in the pedicled grafts

SUMMARY

An experiment on rabbits is reported Pedicled bone grafts were removed from the trochanters the stalks were torqued extended and flexed to obtain an impression of their tolerance The histological and microangiographic investigations of the specimens were supplemented by absorption experiments using Na^{24} The most detrimental process was the torsion which caused total necrosis of the bone The other two procedures did less to reduce the survival of the original cells The grafts preserved an osteogenetic activity in all cases

RÉSUMÉ

Il est rapporté une expérience à laquelle on a procédé chez des lapins Des greffes osseuses pédiculées ont été retirées des trochanters Les pedoncules ont ensuite été tordus étirés et fléchis pour avoir une impression de leur résistance Les examens histologiques et microangiographiques des spécimens ont été complétés par des expériences d'absorption en utilisant du Na^{24} radioactif Le processus le plus préjudiciable a été la torsion qui causa une nécrose totale de l'os Les deux autres procédés ont moins contribué à réduire la survie des cellules originales Dans tous les cas les greffes ont conservé une activité ostéogénétique

ZUSAMMENFASSUNG

Ein Versuch mit Kaninchen wird berichtet Gestielte Knochenspähne wurden von den Trochantern entfernt Die Stiele wurden torquiert gestreckt und gebeugt um einen Eindruck ihrer Widerstandskraft zu erhalten Die histologischen und mikroangiographischen Untersuchungen der Proben wurden mittels Absorptionsexperimenten ergänzt in dem man radioaktives Na^{24} verwendete Das schädlichste Vorgehen war die Torsion da sie vollständige Nekrose des Knochens hervorrief Die beiden anderen Verfahren führten in geringerem Grade zu einer Herabsetzung des Überlebens der ursprünglichen Zellen Die Spähne bewahrten in allen Fällen eine osteogenetische Aktivität

REFERENCES

- 1 Bertelsen A (1944) *Acta orthop scand* 15 139
- 2 Bridges J H & Pritchard J J (1958) *J Anat* 92 28
- 3 Baadsgaard K & Medgyesi S (1965) *Acta orthop scand* 35 279
- 4 Conway H, Roswit B, Stark H B & Yalow R (1951) *Proc Soc exp Biol Med* 77 348
- 5 Medgyesi S (1965) *Acta orthop scand* 35 294
- 6 Trueta J (1963) *J Bone Jt Surg* 45B-2 409
- 7 Urist M R & McLean F C (1959) *J Bone Jt Surg* 41A 443

connection with pedicled skin flaps (4) The test was illustrative and the results were on the whole in conformity with the histological findings The method is simple and appears to afford good orientation concerning the circulation in the pedicled grafts

SUMMARY

An experiment on rabbits is reported Pedicled bone grafts were removed from the trochanters the stalks were torquated extended and flexed to obtain an impression of their tolerance The histological and microangiographic investigations of the specimens were supplemented by absorption experiments using Na^{22} The most detrimental process was the torsion which caused total necrosis of the bone The other two procedures did less to reduce the survival of the original cells The grafts preserved an osteogenetic activity in all cases

RÉSUMÉ

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- 2 Bridges J H & Pritchard J J (1958) *J Anat* 92 28
- 3 Baadsgaard K & Medgvesi S (1965) *Acta orthop scand* 35 279
- 4 Conway H Roswit H Stark R B & Yalow R (1951) *Proc Soc exp Biol Med* 77 348
- 5 Medgvesi S (1965) *Acta orthop scand* 35 294
- 6 Trueta J (1963) *J Bone Jt Surg* 45B-2 409
- 7 Urist M R & McLean F C. (1959) *J Bone Jt Surg* 31A 443

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ANALYSIS OF DIURNAL RATE OF LONGITUDINAL GROWTH OF BONES

By

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Received 3 iii 67

In an investigation of the effects of oxygen breathing on the growth in length from the epiphyseal growth plate with oxytetracycline labelling it proved necessary to ascertain whether such growth has any diurnal periodicity. The possibility of such a rhythm has been suggested by Simmons. Utilizing the colchicine method in growing mice he found the number of mitotic figures in the epiphyseal plates of the distal femur and proximal tibia to be 26.8 per cent respectively 23.3 per cent larger in a night group than in a day group (Simmons 1962). In an other study utilizing glycine C-14 incorporation (Simmons 1966) he established that collagen synthesis and new bone formation had a corresponding rhythm with the greatest activity in the environmental light period 09.00-21.00 although the rats feed most actively at night. He does not say whether this implies a corresponding variation of the growth in length of the metaphysis or an increase in the height of the epiphyseal plate or simply a variation in the activity without any effect on the metric growth in length of the bone. He felt that the day/night differences reflected the diurnal variation of the secretory activity of the parathyroid gland and the adrenal cortex. This diurnal periodicity is reflected by a wide variety of tissues and has also been demonstrated with tritium thymidine in growing bone (Messier & Leblond 1960). The purpose of the present study was to ascertain whether allowance must be made for any such variation in the longitudinal growth rate of the metaphysis of the bone in young rabbits as measured by oxytetracycline fluorescence labelling during short time variation of the oxygen content of the air inhaled.

METHOD

The growth in length of the bone was measured by the technique of *Hansson* (1967). Oxytetracycline in a dose of 1 mg/kg bodyweight was injected *i.v.* into 4 to 6 weeks old rabbits. Such doses do not influence the growth (*Hansson* 1967). Repeated injections at exactly 12 hour intervals mark the position of the zone of calcification on each occasion in sections placed parallel to the metaphyseal trabeculae; these appear in the ultraviolet microscope as parallel lines spaced at intervals corresponding exactly to the growth in length of the metaphysis during each twelve hour period. According to this method the proximal part of the tibia is dissected out, fixed for two days in pure ethanol and sectioned with a razor blade without previous decalcification. The sections are treated for five minutes in xylol and mounted in DePeX. The distance between the lines was measured in 8 to 10 sections from each animal and the means were calculated. The error of the method in the hands of the author has been determined by simultaneous preparations of the left tibia and the right independently and the mean difference was 3.7 per cent (*Persson* 1967).

MATERIAL

The material consisted of 28 white rabbits aged 4-5 weeks from five litters. The animals were kept together with their mothers in hutches in an indoor stable and were given pellets and water *ad lib*. The stable was illuminated by daylight from 5 a.m. to 7 p.m. Each animal received all together 5 injections of oxytetracycline; the interval between consecutive injections being exactly 12 hours to allow 4 semi-diurnal recordings in each animal. The animals were divided into two groups: two litters of totalling 13 animals were given the injections at 13.40 hours and 01.40 hours respectively (in Table 1 called p.m./a.m.) and 15 rabbits belonging to the remaining three litters were given injections at 07.40 and 19.40 hours (in Table II called day/night). The use of this 6 hour difference between the times of the injections in the two groups was intended to reveal any variation possibly concealed by being equally large before and after the time of the injection. By judging from four semi-diurnal observations in each animal it was possible to see if any variation found was repeated in both the consecutive days thereby giving support to a true diurnal rhythm.

RESULTS AND DISCUSSION

The mean values show in Table 2 that the distance was about 1 per cent more during the daytime than at night and in Table 1 about 1 per cent greater in the afternoon than during the morning hours. This tendency was noted in both days in both groups but the differences were too small to be statistically significant using the *t* test. The values noted on the second day were also somewhat lower than those recorded on the first day which is the normal decrease at this age (*Hansson* 1967). Since the 12 hour periods in the two groups overlapped one another by 50 per cent it was possible also to evaluate the

Table 1 Growth distances in microns per each of four consecutive periods of 12 hours and mean values P m is 13 40-01 40 a m is 01 40-13 40

Rabbit No	p m	a m	p m	a m
1	230	210	230	230
2	250	250	260	250
3	220	230	230	230
4	260	240	240	240
5	260	260	250	250
6	270	250	260	240
7	230	240	230	230
8	300	310	300	300
9	260	260	260	240
10	290	290	290	290
11	290	280	300	290
12	290	280	280	290
13	300	310	300	300
Mean value	265	262	264	259

Table 2 Growth distances in microns per each of four consecutive periods of 12 hours and mean values Day is 07 40-19 40 night is 19 40-07 40

Rabbit No	Night	Day	Night	Day
14	280	280	280	290
15	230	240	190	200
16	280	270	290	300
17	270	280	260	270
18	270	270	260	280
19	260	260	260	270
20	270	270	280	270
21	270	280	260	290
22	300	310	300	290
23	260	260	250	260
24	240	280	290	250
25	300	300	300	300
26	300	300	300	290
27	300	320	300	300
28	300	300	300	300
Mean value	277	281	275	277

growth during 6 hour periods. If these 6 hour periods be called a , b , c and d , with period a beginning at 01 40 hours the mean value of $b+c$ will be larger than that of $a+d$, and that of $c+d$ larger than that of $a+b$. Addition of these inequalities will show that $c > a$ that is growth

is greater during 13.40-19.40 than during 01.40-07.40. Normalisation of the means of the observations ($a+b+c+d=1$) will show finally that $d > b$ i.e. growth is greater during 19.40-01.40 than during 07.40-13.40. But since the differences found were about 1 per cent only and statistically insignificant they warrant no final conclusions. It would appear that the growth in length from the epiphyseal growth plate in young rabbits does not vary to any considerable extent from one 6-hour period to another unless diaphasic variation occurs within periods of less than 6 hours a possibility that seems unlikely. Even if such a short diaphasic variation did occur it would in no way influence the value of this tetracycline method for studying growth during consecutive 12 hour periods.

SUMMARY

A diurnal rhythm in the growth of bones has been reported by Simmons. To see whether this rhythm is found in the metric growth in length of the metaphysis in rabbits oxytetracycline labelling was used by repeated injections at 12 hour intervals. The variation found was statistically insignificant the mean differences being about 1 per cent with greater values for the afternoon. Allowance for a diurnal rhythm is not necessary in the use of this method.

RÉSUMÉ

Un rythme diurne de la croissance des os a été rapporté par Simmons. Pour constater si ce rythme se trouve dans la croissance métrique en longueur de la métaphyse chez les lapins on a utilisé une coloration à l'oxytétracycline par injections répétées à 12 heures d'intervalle. La variation constatée est insignifiante statistiquement la différence essentielle étant d'environ 1 per cent avec des données plus élevées dans l'après-midi. La reconnaissance d'un rythme diurne n'est pas nécessaire si l'on utilise cette méthode.

ZUSAMMENFASSUNG

Ein täglicher Rhythmus des Knochenwachstums ist von Simmons berichtet worden. Um zu sehen ob dieser Rhythmus im metrischen Längenwachstum der Metaphyse von Kaninchen gefunden werden kann wurde Oxytetracyclinmarkierung mittels wiederholter Injektion in 12 stündlichen Intervallen verwendet. Die gefundenen Verschiedenheiten

waren statistisch nicht bezeichnend indem die Hauptunterschiede ungefähr 1 prozent mit grosseren Werten am Nachmittag waren. Berücksichtigung eines täglichen Rhythmus ist nicht nötig bei der Anwendung dieser Methode.

REFERENCES

1. Hansson L I (1967) Daily growth in length of diaphysis measured by oxytetracycline in rabbit normally and after medullary plugging. *Acta orthop scand* Suppl. 101
2. Messier B & Leblond C P (1960) Cell proliferation and migration as revealed by radioautography after injection of Thymidine- H^3 into male rats and mice. *Amer J Anat* 106 247-265
3. Persson B M (1967) Effects of hyperbaric oxygenation on the longitudinal growth of bones. *Acta orthop scand* 38 23-24
4. Simmons D I (1962) Diurnal periodicity in epiphyseal growth. *Nature* 195 82-83
5. Simmons D I (1966) Periodicity of S^{35} uptake in rat femurs. *Experientia* 20 137-138
6. Simmons D I & Nichols G (1966) Diurnal periodicity in the metabolic activity of bone tissue. *Amer J Physiol* 210 411-418

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MORPHOLOGICAL CHANGES IN STRIATED MUSCLE DURING ISCHAEMIA

A clinical and histological study in man

By

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Received 27 iv 67

Ischaemia is a prerequisite for modern surgery of the hand. However ischaemia is an unphysiological condition which leads to anoxia of tissues and initiates changes of cellular death. Opinion varies as to how long ischaemia can be maintained without endangering the tissues from 1 to 3 hours being the time usually suggested.

Fishback & Fishback (1932) investigated muscle degeneration following ischaemia. According to them the first change is slight granular clouding with dimming of cross striations of muscle. This is followed first by oedema of fibres with prominent longitudinal fibrils and then by vacuolization granular albuminous and fatty degeneration and further waxy degeneration and disruption of the tissues. *Harman* (1947) made an experimental study of muscle ischaemia in the rat and in the rabbit. He observed increased cross striations while the longitudinal striations decreased and the muscle fibres were more clearly distinguishable from one another than usual as a result of ischaemia. Prolonged ischaemia was followed by so called Bowman's discoid degeneration. In their electron microscopical studies *Moore, Ruska & Copenhaver* (1956) concluded that in post ischaemic degeneration of the muscles the extent of degeneration is not directly a function of time but depends on whether the muscle is stretched or not and on its content of mitochondria. They saw severely damaged and almost normal fibres as early as 20 minutes and as late as 16 hours after the circulation had been restored. *Dahlbäck & Raus* (1966) investigated the morphological changes in cross striated muscle of the rabbit after

ischaemia of varying duration and after post ischaemic periods of varying length. On gross examination they found that oedema of the muscle was already visible after 30 minutes ischaemia. These workers found that the degenerative changes became more marked with increasing duration of ischaemia and such changes were demonstrable after ischaemia of 30 min. The changes were slight as long as the muscle was ischaemic but increased rapidly when the circulation was restored.

Our aim was to elucidate by a histological method the changes occurring in human cross-striated muscle during ischaemia, a search of the literature having failed to reveal any investigation on human material.

MATERIAL AND METHOD

The material was obtained at operation on the hands of 17 patients aged 3 to 46 years. These were reconstructive operations after injuries sustained in accidents which in the majority of cases required tendon reconstruction with the aid of free tendon grafts but in some cases also transposition of tendons.

Exsanguination was achieved in the usual manner by raising the limb and applying Esmarch's bandage and ischaemia was maintained with a tourniquet. The tourniquet pressure was 290-300 mm Hg. In 13 cases the specimen was taken from the palmaris longus muscle, in 3 from the superficial flexor digitorum muscle and in 1 from the extensor carpi ulnaris. The muscle and its tendon were always entirely undamaged and functioning and there was no scar tissue. The specimen was taken from the distal end of the muscle together with the transplant grasping the tendon the muscle was carefully lifted and severed with a sharp knife while the region of the specimen remained untouched by any instrument. When the tendon had been divided from the specimen the latter was immediately fixed in a 4 per cent neutral formal. Paraffin blocks were made in the usual way. Sections from each specimen were stained with haematoxylin-eosin, van Gieson and Gomori's trichromatic staining.

At histological examination particular attention was paid to degenerative and reactive changes (Figures 1, 2, 3, 4).

We did not consider quantitative measurement of the changes possible except by rough estimation. The changes were thus classified as follows:

- 0 no changes
- 1 slight changes
- moderate changes
- 3 severe changes (cf. Dahlbäck *et al.*)

RESULTS

On gross inspection nothing abnormal e.g. no oedema was seen in the specimen.

The histological findings have been compiled in Table 1.

Table 1 Histological changes

Case number	Age in years	Period of ischaemia in minutes	Degeneration			Changes of muscle striation	Inflammatory cell reaction	Increase of sarcolemmal nuclei
			Granular	Vacuolar	Hyaline			
1	9	30	0	0	0	0	0	0
2	46	35	1	0	0	0	0	0
3	50	40	1	1	0	1	0	0
4	35	40	1	1	0	0	0	0
5	26	43	1	0	0	3	0	0
6	37	45	2	1	0	1	0	0
7	39	50	1	1	0	1	0	1
8	10	50	1	1	0	2	0	0
9	16	50	1	0	0	1	0	0
10	38	55	1	1	0	1	1	1
11	33	60	1	1	0	1	1	1
12	25	65	2	1	0	2	1	1
13	25	74	2	1	0	2	1	2
14	18	75	1	1	1	3	0	1
15	18	80	1	1	0	2	1	2
16	27	90	2	2	1	3	2	2
17	40	135	2	2	0	3	1	3

DISCUSSION AND CONCLUSIONS

No macroscopic changes were visible in the specimens taken during ischaemia

After a short period of ischaemia degeneration is at most slight Granular degeneration was noticed in all except case no 1 with ischaemia of only 30 minutes The degree of degeneration varied and it had a tendency to increase with the period of ischaemia Vacuolization and hyalinization did not appear before 40 minutes ischaemia After ischaemia of 1 hour or more signs of degeneration became numerous even before the circulation was restored

The inflammatory cell reaction was seen first after 55 minutes ischaemia It was always slight but clearly increased with longer periods of ischaemia

No haemorrhages were seen Slight erythrocyte extravasation might have been the result of pressure by Fsmarch's bandage In ischaemia of more than 1 hour an observation pointing to oedema was separation of the muscle fibers and an increased space between the fibrils while



Figure 1 (Case 10)—Muscle specimen after 30 minutes ischaemia Variation of striation and early degenerative changes $\times 120$ Photographed in polarized light



Figure 2 (Case 13)—Muscle specimen after 75 minutes ischaemia Variation of striation and degeneration $\times 120$ Photographed in polarized light

cross striation simultaneously increased. These changes were also a function of time.

The amount of sarcolemmal nuclei increased with increasing duration of the ischaemia.

We may conclude that capillary and cell damage caused by ischaemia become histologically demonstrable after ischaemia of more than 30 minutes duration. The changes are mild, however, until about 2 hours after the onset of ischaemia. It should be mentioned that in none of the patients were there any postoperative signs indicative of irreversibility of the changes occurring during or after ischaemia.

The aggravation of the changes occurring after restoration of the circulation which, according to earlier reports and clinical observations (hyperaemia, oedema), seem probable, could not be investigated in this connexion.



Figure 3 (A B) (Case 17)—Severe degenerative changes in striated muscle after 135 minutes ischaemia Note loss of striation and increase of nuclei $\times 120$

SUMMARY

A study was made of the histological changes visible in muscle specimens taken from 17 patients undergoing surgery of the hand after tourniquet ischaemia of varying duration

It appeared that degenerative changes of the muscular tissue oedema and the inflammatory cell reaction as well as the number of nuclei increased with prolonged ischaemia

The changes were slight at first but increased when the ischaemia

had been maintained for about 35 minutes and became more marked with time

Postischaemic changes were not investigated

RESUME

Il a été procédé à une étude des altérations histologiques visibles dans des spécimens de muscles prélevés chez 17 malades ayant subi une intervention chirurgicale dans la main après ischémie au tourniquet de durée variable

Il est apparu que les altérations dégénératives du tissu musculaire l'œdème et la réaction inflammatoire des cellules de même que le nombre des noyaux augmentent lorsque l'ischémie est prolongée

Les altérations étaient légères au début mais augmentent lorsque l'ischémie est maintenue pendant environ 45 minutes devenant plus marquées avec le temps

Il n'a pas été fait de recherches sur les altérations post-chirurgicales

ZUSAMMENFASSUNG

Eine Studie der histologischen Veränderungen in Muskelproben wurde an 17 Patienten vorgenommen die während handchirurgischen Operationen Blutleere verschiedener Dauer unterworfen waren

Es zeigte sich dass die degenerativen Veränderungen des Muskelgewebes Ödem und entzündliche Zellreaktion und auch die Zahl der Zellkerne mit der Verlängerung der Blutleere zunahm

Die Veränderungen waren im Beginn nur leicht nahmen aber zu wenn die Blutleere für ungefähr 45 Minuten aufrechterhalten wurde und wurden mit der Zeit mehr ausgesprochen

Postischaemische Veränderungen wurden nicht untersucht

REFERENCES

- Dahlbäck L O & Reis O (1966) Morphologic changes in striated muscle following ischemia Immediate postischemic phase *Acta chir scand* 131 430
 Fishback D H & Fishback H R (1932) Studies of experimental muscle degeneration 1 Factors in the production of muscle degeneration *Amer J Path* 8 193
 Fishback D H & Fishback H R (1932) Studies of experimental muscle degeneration *Amer J Path* 12 193

- Harman J W (1947) A histological study of skeletal muscle in acute ischemia
Amer J Path 23 551
- Moore H., Ruska H & Copenhaver W M (1956) Electronical microscopic and histochemical observations of muscle degeneration after tourniquet *J biophys biochem Cytol* 2 755

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METABOLIC CHANGES IN THE UPPER LIMB DURING TOURNIQUET ISCHAEMIA

A Clinical Study

By

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A bloodless field is essential in surgery of the upper limb. But there are risks involved in maintaining it, the greatest of which is probably ischaemia of unduly long duration. Some workers attribute so called tourniquet paralysis to ischaemia (Bentley & Schlapp 1943, Dery, Peltier, Jacques, Clavel & Houde 1965). All tissues doubtless suffer from ischaemia which actually represents the beginning of tissue death. Negovski (1962) established a metabolic condition similar to that occurring in an ischaemic limb in the blood of patients in terminal states or during clinical death. The tissue changes are best studied in histologic specimens but it is only exceptionally possible to obtain such material *in vivo* without harm to the patient. Capillary blood is in metabolic equilibrium with the tissue in question especially when the blood flow is stopped. In such circumstances blood taken from a vein behind the capillary bed obviously possesses the same properties as capillary blood. This being the case it is possible to elucidate metabolic phenomena of the tissues by means of certain haematologic studies. The purpose of the present work was to study the metabolic changes demonstrable in the blood after varying periods of ischaemia in connection with operations on the upper limb.

MATERIAL AND METHOD

The series comprised 110 patients aged 13-58, mean age 28.5 years. A reconstructive operation of the hand of varying duration was performed on all the patients. The duration of ischaemia was 35-155 min, mean 99 min.

A common note

In the tables the solid line represents the average values for the limb kept in ischaemia the dotted line the average values for the intact limb. The vertical lines show the deviation of determinations. The black spot on the left indicates the average of determinations before the beginning of anaesthesia.

Table 1 pH determinations after opening the tourniquet

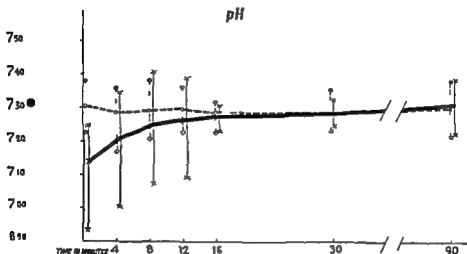
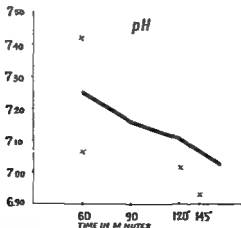
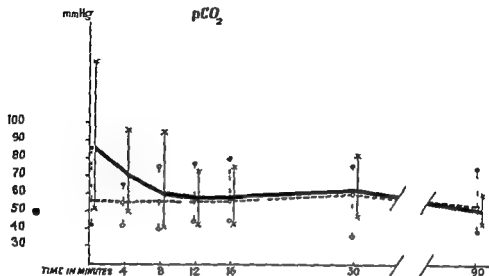
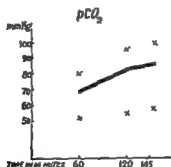


Table 2 pH as a function of the duration of ischaemia (the operated limb)



The anaesthesia given in 15 cases was combined thiopentone halothane-nitrous oxide. The patients were intubated but breathed spontaneously. The oxygen content of the anaesthetic gas mixture was 37 per cent. The patients' acid base balance was normal during surgery before the tourniquet was opened.

Table 3 $p\text{CO}_2$ determinations after opening the tourniquetTable 4 $p\text{CO}_2$ as a function of the duration of ischaemia (the operated limb)

Five patients were operated under plexus anaesthesia

Neither the temperature of the operated limb nor that of the patient was measured during the operation

The following determinations were made: acidity (pH), PCO_2 , standard bicarbonate base excess (BE), pO_2 , potassium, pyruvic acid, lactic acid, creatine phosphokinase (CPK). Blood specimens were taken from the cubital vein or the forearm vein both from the operated and from the contralateral arm in a following series:

1. 5 ml was drawn into a heparinised syringe for blood gas analysis, care being taken that no air entered the syringe
2. 10 ml was drawn into three separate tubes for determination:
 - a. of potassium,
 - b. of lactic and pyruvic acid: proteins were precipitated with perchloric acid immediately after taking the sample, and
 - c. of CPK.

Table 5 Standard bicarbonate determinations after opening the tourniquet

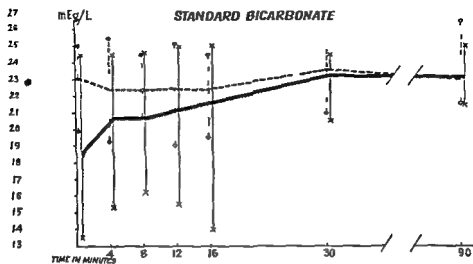
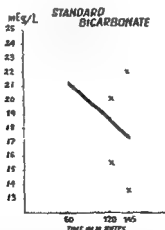


Table 6 Standard bicarbonate as a function of the duration of ischaemia (the operated limb)



The series of samples were taken at the following times

- 1 from the healthy upper limb only before anaesthesia. All the following samples were taken simultaneously from both upper limbs
- 2 immediately after the opening of the tourniquet
- 3 4 min later (4)
- 4 4 min later (8)
- 5 4 min later (12)
- 6 4 min later (16)

Table 7 Base excess determinations after opening the tourniquet

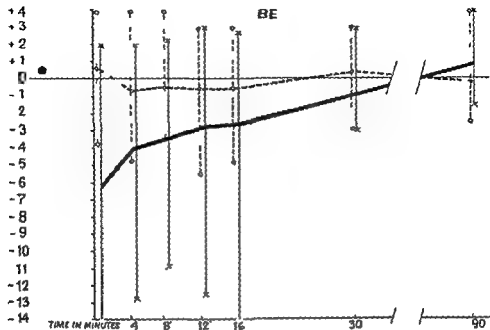


Table 8 Base excess value as a function of the duration of ischaemia (the operated limb)

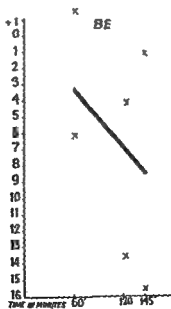


Table 9 pO_2 determinations after opening the tourniquet. The double line represents the average values for patients under plexus anaesthesia (the operated limb)

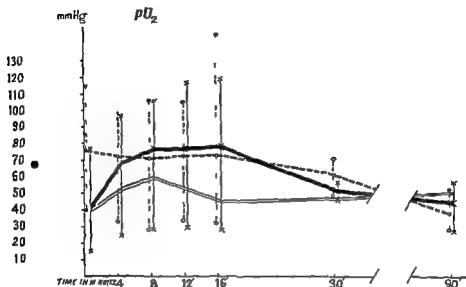
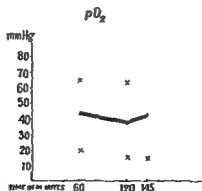


Table 10 pO_2 values for the upper limb kept in ischaemia correlated with the duration of ischaemia



7 14 min later (30)

8 80 min later i.e. 90 min after opening the tourniquet (90')

The time of sampling was recorded. It was impossible to avoid small deviations from the timetable.

The laboratory tests were performed by the following methods:

Blood pH, pCO_2 , standard bicarbonate and base excess were measured in the blood pH meter devised by Astrup *et al.* (1960).

Table 11 Lactate determinations after opening the tourniquet

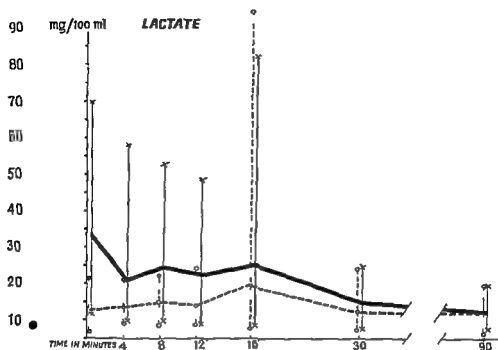
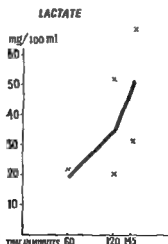


Table 12 Lactate concentration as a function of the duration of ischaemia (the operated limb)

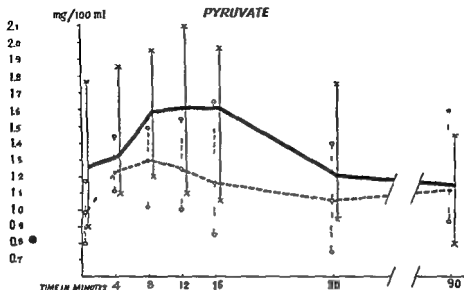
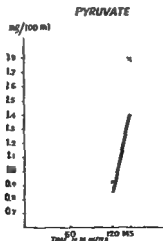


An oxygen electrode was used for the pO_2 measurements (Radiometer 1963)

Lactate pyruvate and creatine phosphokinase were measured by the enzymatic method (Biochemia Boehringer 1961-1965)

An EEL flame photometer was used for the determination of potassium

The results are given in Tables 1-16

Table 13 *Pyruvate determinations after opening the tourniquet*Table 14 *Pyruvate as a function of the duration of ischaemia (operated limb)*

DISCUSSION

Although the pH was distinctly lowered its mean minimum 7.14 was not particularly low. The normal pH of venous blood is 7.30-7.40 (Thorén 1960). The pH value may fall much lower in some pathologic conditions (Siggaard Andersen 1963). Acidity may reach the level of

Table 15 Potassium determinations after opening the tourniquet

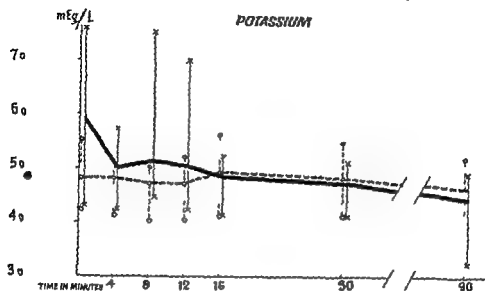
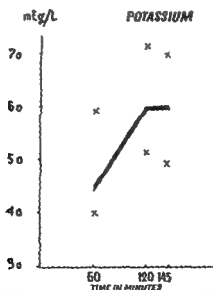


Table 16 Potassium values in correlation with the duration of ischaemia



the intact limb in 16 min. The organism is thus well able to compensate the drop in the pH level following the opening of the tourniquet. When the duration of ischaemia is prolonged the pH declines almost linearly. It falls to close to 7.0 during ischaemia of over 2 hours. This pH value is nearly the same as the intracellular pH (Billar 1964).

The change in $p\text{CO}_2$ is not great for the length of the ischaemic periods though the mean 85 mm Hg is acidotic. Elevation of the $p\text{CO}_2$ value as a function of the ischaemic period is not steep. The $p\text{CO}_2$ may rise to over 150 mm Hg in some pathologic conditions (*Siggaard Andersen*) and therefore the values in the present study cannot be regarded as very high.

Metabolic acidosis according to the standard bicarbonate and base excess values is not pronounced but its neutralisation is slower than the normalisation of $p\text{CO}_2$. This is because the elimination of acid metabolites takes longer than the diffusion of CO_2 from tissues to blood. BE values of about -30 are measured in certain acidotic conditions (*Siggaard Andersen*) and the lowest mean -6.1 of our measurements was thus not very low.

The partial pressure of oxygen does not drop as a function of time. The processes which take place in an ischaemic limb after more than one hour are obviously partly anaerobic. Considerable dissociation of oxygen of myoglobin occurs only after the $p\text{O}_2$ has fallen below 10 mm Hg. Obviously some such situation has prevailed during ischaemia. However the oxygen stores of myoglobin are not appreciably depleted judging by the $p\text{O}_2$ values. The percentage dissociation of myoglobin when $p\text{O}_2$ is 40 is about 90 and there is consequently considerable oxygen supply left at that time.

It is possible that after the tourniquet is opened the cells are incapable of taking up oxygen rapidly from the inflow of arterial blood to the tissue that has been ischaemic and that a part of the oxygen containing blood by-passes the capillaries via shunts between arterioles and venules. However the situation becomes normal fairly rapidly and after five minutes the $p\text{O}_2$ values are the same in both upper limbs. It must be remembered that the blood oxygen concentration in a patient under general anaesthesia depends on the oxygen content of the gas mixture used. The $p\text{O}_2$ values for patients under plexus anaesthesia are therefore given separately. These patients breathed only air.

The potassium value rose to 6.1 mEq/l after two hours of ischaemia and appeared to persist at that level even with continued ischaemia. The potassium value became normal rapidly after removal of the tourniquet i.e. within four minutes. Only a small quantity of potassium seems to escape from the tissues in these operations and during ischaemia. The intracellular potassium value is normally about 30 times the extracellular value. The balance depends on the energy supply. When the supply of energy is inhibited some potassium obviously

escapes from the cells. A surgical injury can also contribute to the elevation of the potassium content. This makes it all the more obvious that our measures did not greatly upset the energy balance of the tissues.

The pyruvate values continued to rise after the opening of the tourniquet. The explanation may be that glycolysis produced pyruvate from glycogen and that it is not disintegrated immediately by catabolism. However, the amount of glycogen produced energy is probably small since the elevated $p\text{CO}_2$ inhibits the anaerobic decomposition of glycogen to lactate. The lactate concentration remained elevated for some 30 min after the removal of the tourniquet but the values were not high. The lactate concentration rises steeply as a function of the duration of ischaemia.

The concentration of lactate and pyruvate are not directly correlated with the BE changes. The reason for this phenomenon is discussed elsewhere (Narvanen 1966).

The observation period appeared to be too short for CPK determinations.

CONCLUSIONS

Although a metabolic balance prevails between tissues and blood its dynamic character does not warrant far reaching conclusions.

Ischaemia induced acidosis is not particularly severe. It displays features of both metabolic and respiratory acidosis. The acidosis is neutralised rapidly as the circulation returns to normal.

Anoxia during ischaemia is corrected rapidly. It seems that there is no large demand on the oxygen reserves of the myoglobin in the muscular tissue.

In view of the paucity and the deviation of the findings it would be venturesome to draw conclusions on the basis of the lactate/pyruvate ratio. The rather slight increase in the potassium value shows that both the ischaemia and the operation caused only a slight tissue trauma from the energy standpoint.

Transfer of energy between muscle cell and nerve cell is difficult to discuss on the strength of these results.

As the limb to be operated on is hypothermal because of ischaemia (Dery *et al.*) the metabolic processes slow down. When our results are compared with known characteristics of muscle metabolism it may perhaps be said that muscular tissue at any rate has sufficient energy

reserves to maintain post ischaemic recuperation processes when the ischaemia is as long as it was here

That acidotic blood with a high CO_2 content rushes into the systemic circulation at the moment ischaemia is discontinued may be of clinical significance. The elevated pCO_2 may aggravate the fall in blood pressure which is always demonstrable when the tourniquet is removed and the vessels of the exsanguinated limb fill with blood. The high CO_2 concentration probably causes vasodilatation and exacerbates the irritability of the myocardium. If the myocardium is sensitised to arrhythmia in advance *e.g.* by adrenalin or halothane such an increase in acidosis may lead to a functional cardiac disorder. This is particularly true of patients who have previously been acidotic, have poor pulmonary function and a previously elevated CO_2 value. However the acidosis after the ischaemic phases described here is so mild and of such short duration that it can hardly harm a patient in good condition.

SUMMARY

The metabolic changes caused by tourniquet ischaemia were studied in 20 patients subjected to reconstructive operation on the upper limb. All the determinations were made in venous blood. Moderate acidosis was established in the ischaemic limb. The condition was metabolic acidosis in which the carbon dioxide content was elevated. The acidosis increased as a function of the duration of ischaemia but disappeared rapidly when the circulation was normalised. The blood potassium rose to an average of 6.1 mEq/l . The lactate and pyruvate content increased as a function of the duration of ischaemia but neither reached high levels. Both the ischaemia and the surgical intervention seem to have caused only a slight and rapidly corrected tissue injury as far as energy balance is concerned.

RÉSUMÉ

Les modifications métaboliques causées par ischémie au tourniquet ont été étudiées pour 20 malades chez lesquels il a été procédé à une opération reconstructive du membre supérieur. Toutes les déterminations ont été faites à partir du sang veineux. Une acidose modérée a été constatée dans le membre ischémique. Il s'agissait d'une acidose métabolique dans laquelle la teneur en carbone dioxide était plus élevée. L'acidose s'est accrue en fonction de la durée de l'ischémie mais disparaît rapidement dès que la circulation fut à nouveau normalisée. La potassium de

sang ■ est élevée à une moyenne de 6.1 mEq/l. La teneur en lactate et pyruvate s'est accrue en fonction de la durée de l'ischémie mais n'a jamais atteint un niveau très élevé. Tant l'ischémie que l'intervention chirurgicale ne semblent avoir causé qu'une faible lésion tissulaire rapidement corrigée en ce qui concerne l'équilibre de l'énergie.

ZUSAMMENFASSUNG

Die metabolischen Veränderung die durch Blutleere bei 20 Patienten entstanden an denen eine Wiederherstellungsoperation der oberen Gliedmasse ausgeführt worden war wurden untersucht. Alle Bestimmungen wurden an venosem Blut gemacht. Moderate Acidose wurde an der ischämischen Gliedmasse festgestellt. Der Zustand war eine metabolische Acidose in der der Carbondioxidinhalt erhöht war. Die Acidose nahm als eine Funktion der Dauer der Blutleere zu verschwand aber rasch wenn die Zirkulation wiederum normal wurde. Der Blutkaliuminhalt stieg zu einem Durchschnitt von 6.1 mEq/l. Der Laktat und Pyruvatinhalt stieg als eine Funktion der Dauer der Ischämie aber keiner von beiden erreichte hohe Werte. Sowohl die Blutleere als auch der chirurgische Eingriff scheinen nur einen leichten und rasch korrigierten Gewebsschaden hinsichtlich des Energiegleichgewichtes hervorgerufen zu haben.

REFERENCES

1. Astrup P, Jørgensen K, Siggaard Andersen O & Engel K (1960) The Acid Base Metabolism: A New Approach. *Lancet* 1 1035
2. Bentley F H & Schlapp W (1943) Experiments on the Blood Supply of Nerves. *J Physiol* 102 62
3. Biochemica Boehringer C F Boehringer & Soehne (MBH Hamburg 1961-1963)
4. Hittar F F (1964) Cell pH. Butterworths London
5. Déry R, Pelletier J, Jacques A, Clavel M & Houde J J (1965) Metabolic Changes Induced in the Limb During Tourniquet Ischaemia. *Can Anaest Soc J* 12 367
6. Negovskii V A According to Déry R et al
7. Narvanen M (1966) Chemical and Hematological Changes During extracorporeal Circulation. *Scand J clin Lab Invest* 18 Suppl 91
8. Radiometer Copenhagen Denmark (1963) Instruction and Operating Manual for pO₂ Electrode Type E 5044 and pO₂ Electrode Assembly Type E 5045
9. Siggaard Andersen O (1963) The Acid Base Status of the Blood. *Scand J clin Lab Invest* 15 Suppl 70
10. Thorén L (1960) Vatskebalans. Almqvist & Wiksell Uppsala

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COLLES FRACTURE OPERATIVE TREATMENT, INDICATIONS AND RESULTS

By

ÅMUND KRISTIANSEN & FINAR GJERSØE

Received 2 iv 67

Colles fracture in Scandinavia generally termed *fractura radii typica* belongs to the most frequent type of fracture. During the last five years 1961-1965 the Emergency Service registered 57426 fractures a total of which 10729 or about 18.7 per cent were *fractura radii typica*. A number of reports have been made on the results of conventional treatment of this type of fracture among others the works of the Scandinavians Nissen-Lie (1939), Rosen (1947), Madsen (1949), Wicklund & Mullern-Aspegren (1956) and Lidstrom (1959).

Nissen-Lie's grouping of fractures of the lower end of the radius has been generally accepted as a classification basis in the Scandinavian reports.

- I Fractures on the passage between the scapula and the lower end of the radius most frequent in children one to fifteen years of age
- II Epiphyseolysis in children and youths ten to twenty years of age
- III Fractures through the lower end of the radius without dislocation
- IV *Fractura radii typica* (Colles) with dorsal and volar dislocation
 - V Commune fractures with one or more communications to the joint
 - VI Isolated fractures of the styloid process of the radius
 - VII Fractures with volar dislocation (Smith's)

The following are the results of Nissen-Lie's report which covers 282 re-examined cases classified as above.

- I 45 cases All healed without lasting injury
- II 32 cases All healed without lasting injury
- III 57 cases 52 healed without lasting injury and 5 healed with a slight radial deviation
- IV & V 143 cases of dislocated and partly comminute fractures of which 133 were controlled about one year after the time of injury 103 (73 per cent) were free of symptoms and had full mobility 16 (12 per cent) had slight radial deviation 12 (9 per cent) expressed pain (only by use) 9 (7 per cent) had reduced mobility 8 (6 per cent) showed marked radial dislocation
- VI 10 cases All free of symptoms
- VII 5 cases All healed with a slight radial deviation otherwise free of symptoms

In his report *Nissen Lie* classifies 26 cases healed with slight radial deviation as satisfactorily healed thus giving an extremely low number of unsatisfactorily healed cases representing only about 5 per cent of the total and referring mainly to the displaced and comminute fractures in the groups IV and V

Madsen reports a redisplacement of 39 per cent of the cases in group IV and 75 per cent in group V

In addition *Lidstrom* stresses the evident connection between the intra articular fractures and the unsatisfactory results in his report representing 8 per cent of the total number of cases

On the other hand *Bacon & Kurtzke* state that the average disability was 24 per cent in a study made of 2132 cases of Colles fracture from the New York State Workmen's Compensation Board while only 29 per cent of the cases were judged to have no permanent disability. However X ray examination of the anatomical results usually reveals a somewhat different picture

In *Nissen Lie's* groups IV and V 70 per cent of the cases showed ideal initial reduction in which a total of 60 per cent had a 4 mm or more shortened radius as a final result. Furthermore 80 per cent of the cases in *Nissen Lie's* groups IV and V showed varying degrees of clinical deformity of the hand in eight cases characterized as severe and in twenty six cases as light. In comparison *Lidstrom's* total material shows redisplacement in 28 per cent of the cases

These facts indicate as commonly accepted that poor anatomical or

cosmetic results are not necessarily connected with unsatisfactory functional results

Lidstrom draws the following conclusions in his report

- 1 The prognosis was less favourable for intra articular fractures than for other types of fractures
- 2 Final deformity increased the risk of impaired function
- 3 Posttraumatic causalgia was to a certain degree permanent with consequent loss of function
- 4 Residual laxity in the distal radio-ulnar joint increased the risk of reduced function

In connection with the second paragraph of the conclusions it seems natural to consider alternative precautions to prevent deformity during or after reunion for example through operative corrections

Surgical interventions have been performed on this basis partly as osteotomies to correct deviations partly by bone grafting to correct disproportions between the radius and the ulnae in cases of shortened radius. These procedures where grafts from the distal end of the ulnae or from the distal end of the upper radial fragment are wedged into the osteotomy of the lower end of the radius have been described respectively by *Campbell* (1937) and *Durman* (1937). Ulnar pinning to prevent displacement was described by *De Palma* (1930) and closed medullary pinning by *Rush* (1934). Other operations have also been performed in order to improve mobility for instance through resection of the lower end of the ulnae according to the original *Darrach* method.

In his report *Lidstrom* recommends the following directions for operative correction

- 1 The deformity should be severe
- 2 Sufficient time must have elapsed after time of injury
- 3 There should be no symptoms of posttraumatic disturbances or nerve injuries
- 4 There should be no comminution of the articular surface or arthritis of the radio carpal joint
- 5 Operative correction of radio ulnar instability is only indicated in cases where the capitulum ulnae is displaced out of the ulnar notch

After thorough investigation *A. Kristensen* has worked out a method to prevent or correct final deformity of the radius. The method is based

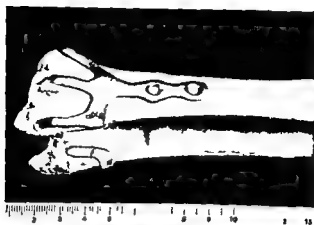


Figure 1 Photo of the K splint in situ on a radial bone pictured with a mirror as background thus showing both the dorsal and ventral side

on the principle of restoring the anatomical conditions by bone grafting combined with an internal fixation of the fragments by means of a specially constructed surgical appliance

In our opinion the method will ensure better results for operations in the region of the radio carpal joint although the close anatomical relations in this area make surgical intervention rather complicated compared to operations on fractures adjacent to other joints of the extremities

Close anatomical studies indicated the construction of an appliance later called the K splint which is hand shaped with three fingers on the dorsal side and one finger on the radial side (Figure 1) The finger on the radial side like a thumb bends around the styloid process keeps this in position and continues on the other side to support the volar aspect of the radius

The original intention was to locate the three fingers between the tendon channels

Due to deformity and loss of structure and bone substance the exact indicated positions of the fingers are often difficult to obtain Practice proves however that this does not influence the final result

The K splint is produced in three sizes from an alloy which like the original Vitallium consists of cobalt chromium and molybdenum In addition there is a T shaped appliance specially constructed to support the volar face of the radius in cases of Smith's fracture

A retractor has also been constructed one for each hand This re

tractor allows a steel wire inserted between the radius and the surrounding soft tissues to be stretched without interfering with X-ray examinations during operation.

Furthermore a pair of modified Lambotte's forceps adjusted to the broad volar aspect of the radius on one side and to the splint on the other side is recommended to lock the splint to the radius. A pair of standard forceps for final adjustments of the K-splint's fingers is also required.

THE OPERATION

The skin incision starts at the base of the thenar and continues with a slight dorsal curve along the tendon of the long abductor and short extensor muscles of the thumb. Then on reaching the dorsal side of the radius the incision is slightly curved in a volar direction up to a handbreadth above the radio-carpal joint. The fascia is divided along the superficial radial nerve which together with its branches to the thumb is exposed up to the crossing with the brachio-radial muscle. Here the nerve leaves the fascial layer and is to be exposed by a pair of scissors with edge turned dorsally to divide the connective tissue between the brachio-radial and extensor carpi radialis muscles. The nerve is retracted dorsally. The brachio-radial muscle is loosened by subperiosteal dissection from its insertion at the styloid process of the radius and retracted in volar direction. The periosteum is divided corresponding to the edge of the radius and the fragments exposed by careful dissection in the subperiosteal space.

Having obtained a good general view of the fracture and the crossed zone of bone a suitable block of cancellous bone (without the cortical layer) is chiselled out of the iliac crest and trimmed to replace the crossed part of the bone. The K-splint is fixed to the proximal fragment by two screws. The fingers of the splint will then keep the distal fragments and the bone in position. If necessary adjustments are made by the insertion of small cancellous bone grafts.

During the first ten days of aftertreatment a simple volar splint is recommended. After the sutures are removed a plaster cast is applied for 8-12 weeks.

X-ray examinations with a carefully standardized technique are carried out during the operation, two to seven days after the operation and repeated every two or four weeks until the fracture is consolidated.

THE CASES

This report covers a total of twenty six patients operated and followed up by Amund Kristiansen reexamined and evaluated by Einar Gjersøe. Data are insufficient in three cases all referring to older patients that died of other reasons during the follow up period.

The remaining twenty-three cases consist of Twenty two patients with Colles fracture and one Smith's fracture.

The age of the three male and twenty female patients varied from thirty to seventy two years giving an average age of fifty five years.

Indications

- I Six patients had impaired function and/or pains as result of mal united fractures. Operations were performed between 41 and 189 days after injury.
- II Seventeen patients had redislocated fractures which were operated before the end of the reunion period. These patients were operated upon between 3 and 29 days after injury.

Complications

- I Three cases of lesion of the dorsal skin innervation of the thumb immediately treated with nerve sutures.
- II Two cases of superficial infection.
- III In four cases the h. splint was removed in one case because it loosened after reunion and in one case because it broke. In two cases the splint became too long after a second reduction of the length of the radius thus interfering with the free movements of the hand.

Reexamination

The average observation time in this report is four years and five months varying from two years and ten months to nine years and six months.

At reexamination the following results were evaluated

- 1 Anatomical results
- 2 Mobility
- 3 Pains

The patient's uninjured hand has been used as an evaluation basis for the anatomical results. In cases of previous fractures of the other

hand the average values of this report's uninjured hands have been used for comparison

Articulation surface in frontal projection 116

Articulation surface in lateral projection 81

Level difference between the point of the styloid process of the radius and the capitulum ulnae (called d) 12 mm

These values correspond with the normal values indicated by de Palma who states 120/105 in frontal projection and 89/67 in lateral projection with an average of respectively 113 and 79

Like Nissen Lie and others we have used the difference in distance (distance = d) between the top of the styloid process of the radius and the plane through the distal articular surface of ulnae as one method to measure shortening and redisplacement

Usually the shortening is located on the radial side and in these cases the difference in d gives the actual shortening

As this method of measuring the reduced length does not cover a possible shortening on the ulnar side of the radius we have consequently measured the ulnar shortening, or the distance between the distal ulnar corner of the radius and the plane through the distal articular surface of the ulnae and for practical reasons graded the distance as follows

$$\begin{aligned} &+ \quad 1-5 \text{ mm} \\ &+ + \quad 6-10 \text{ mm} \\ &+ + + \quad \text{more than } 10 \text{ mm} \end{aligned}$$

The same system has been used in order to grade the volar displacement by measuring the distance between the most prominent part of the volar displaced fragment and the volar aspect of the radius and the dorsal displacement by measuring the distance from the most prominent part of the dorsal-dislocated fragment to the dorsal aspect of the radius

Final anatomical results

The results of the operations performed and covered in this report have been divided into the following groups

- I Excellent anatomical results This group consists of seven patients all with joint surfaces differing less than 10 in one or both projections from the uninjured hand In four cases the divergence is less than 5 and in all cases there is none or only minor reduction of d (less than 5 mm) and no ulnar shortening

- II Good anatomical results Six patients belong to this group. In these cases the articulation surface has a divergence of maximum 20° in one or both projections and the reduction of d is less than 10 mm. The ulnar shortening does not exceed 5 mm (called +) and the angle of the articulation surface is less than 90° in the lateral view.
- III Fair anatomical results This group includes four patients, all with an ulnar shortening of the radius not exceeding 10 mm (called ++). In one case the articulation surface has a divergence of 24° in the lateral projection. In the other cases the divergence is less than 20° in one or both projections. In two cases the angle of the articulation surface is more than 90° in the lateral view.
- IV Poor anatomical results In this group, which consists of six patients, the result may be characterized as less favorable than in group III. All patients have some dislocation ad rum . In five cases the angle of the articulation surface is not satisfactory.

Function

In cases that permit such a comparison, the evaluation of the mobility has been based on the movements of the uninjured hand. In the other cases the normal rates given by the Committee of Medical Rating and Physical Impairment (JAMA spec ed febr 15 1958) have been used in comparison. According to this rating, and in order to measure the function of the wrist, the lasting impairment has been judged without taking into consideration the patient's subjective troubles. The following movements have been measured: Dorsal, volar, radial and ulnar flexion, pronation and supination. These are the results:

0-5 per cent mobility impairment eight patients

6-10 per cent mobility impairment ten patients

11-20 per cent mobility impairment five patients

Subjective Symptoms

Of the thirteen patients in groups I+II, three had grumbling in the hand with weather changes and three reported some hypoaesthesia on the dorsum of the thumb. All patients in these groups stated that they had full working ability.

Of the ten patients in groups III+IV, one patient had difficulty in

holding heavy things in maximal pronation and minimal supination of the hand. This patient presented fracture and nerve injury at the time of injury.

One patient, a waitress, reported that she was unable to carry trays with her hand in supination although she had full mobility in the hand. In two cases, minor sensory nerve disturbances were observed on the dorsal side of the thumb.

One patient complained about lasting pains in the injured wrist caused by arthritis and arthrosis. This patient, sixty-one years of age, has a full-time job as a cashier. The other patients consider their minor defects to be of no importance and are all consequently fully employed.

On the whole, twenty-one patients are very well pleased with the results obtained and consider their hands to be as good as before the injury. Only two patients do not belong to this satisfied group, namely the one who has certain difficulties in performing her job as a waitress and one who is not satisfied because of pains.

DISCUSSION

The above cases, with a few exceptions, represent severe and complicated fractures which have all healed with satisfactory functional results despite proved or indicated unsatisfactory results from earlier treatment.

The technically difficult method demands, however, both experience and skill from the operator.

Operations of this kind are specially difficult to perform between two and six weeks after the time of injury because of the fragility of decalcinated bone or in other words when indications clearly show the necessity for operation. Case determination and operating performance at an earlier stage will, however, reduce the degree of difficulty and save the patient's time. These are our general remarks concerning the conditions which in our opinion should be taken into consideration.

The stability of a fracture in the lower end of the radius of an unloaded arm is based upon

- A The muscles and their acting on the fragments
- B The fracture plane at an angle to the axis of the radius which influences the leverage of the muscles

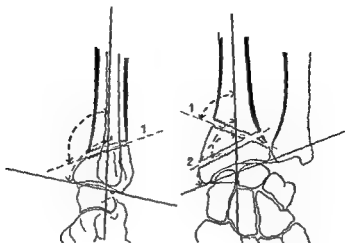


Figure 2 Drawing of a radial fracture. In case of fractures with fracture line 1 the action of the pronator muscles especially the quadratus may draw the scapus fragment towards ulnae while the distal fragment tangential ulnae at the distal radio ulnar joint remains in situ turning only a few degrees around the dorso ventral axis thus fracture line 2 the action of the pronators force the scapus fragment to grasp the distal fragment thus helping to keep this in position and to stabilize the fracture

The extensor and flexor muscles pull the distal fragment mainly in proximal direction but to a certain degree also in dorsal or ventral direction according to the position of the hand and the fragments

The general action of the pronators and supinators in relation to the movements of the hand and forearm is well known. Less considered however, is the action of the pronator quadratus, and to a certain degree the action of the pronator teres which both try to pull the scapus fragment of the radius towards ulnae. The result of this action is of great importance to the stability of the fracture.

A 90° or more angulation of the fracture line in frontal view increases stability while a smaller angle reduces stability. On the above outline (Figure 2) of a Colles fracture fracture line no. 1 of the frontal view shows that the scapus fragment may be drawn ulnar until its distal ulnar corner contacts ulnae while the distal fragment tangential ulnae at the distal radio ulnar joint remains in position turning only a few degrees around the dorso ventral axis. The dislocated fracture seems in other words to be a radial displacement of the distal fragment while it actually is an ulnar displacement of the proximal fragment.



Figure 3A A typical Colles fracture case no 14



Figure 3B The result after three weeks of treatment in a plaster cast



Figure 3C The final result

Fracture line no 2 shows clearly how the proximal fragment will contact the distal fragment and keep this in position

The lateral view of the fracture indicates how an angle of more than 90° facilitates a displacement of the distal fragment in the dorsal direction. In the same way an angle less than 90° lightens a displacement in the ventral direction.

A rough fracture surface will of course increase the friction, but the stability of a fracture depends first of all on the size of the crossed zone of bone. This is usually wedge shaped with the base on the dorsal side and the edge on the ventral side, a shape due to the direction of the injury and to the thin, crisp cortical layer on the dorsal side. The thick, strong cortical layer on the ventral side, however, usually prevents the distal fragment from being impacted in the proximal one, which occurs quite often on the dorsal side.

On the whole, one may say that the resorption of bone increases with

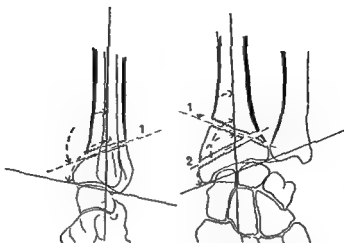


Figure 2 Drawing of a radial fracture In case of fractures with fracture line 1 the action of the pronator muscles especially the quadratus may draw the scapus fragment towards ulnae while the distal fragment tangential ulnae at the distal radio ulnar joint remains in situ turning only a few degrees around the dorso ventral axis thus fracture line 2 the action of the pronators force the scapus fragment to grasp the distal fragment thus helping to keep this in position and to stabilize the fracture

The extensor and flexor muscles pull the distal fragment mainly in proximal direction but to a certain degree also in dorsal or ventral direction according to the position of the hand and the fragments

The general action of the pronators and supinators in relation to the movements of the hand and forearm is well known Less considered however is the action of the pronator quadratus and to a certain degree the action of the pronator teres which both try to pull the scapus fragment of the radius towards ulnae The result of this action is of great importance to the stability of the fracture

A 90° or more angulation of the fracture line in frontal view increases stability while a smaller angle reduces stability On the above outline (Figure 2) of a Colles fracture fracture line no 1 of the frontal view shows that the scapus fragment may be drawn ulnar until its distal ulnar corner contacts ulnae while the distal fragment tangential ulnae at the distal radio ulnar joint remains in position turning only a few degrees around the dorso ventral axis The dislocated fracture seems in other words to be a radial displacement of the distal fragment while it actually is an ulnar displacement of the proximal fragment

ing combined with an internal fixation of fragments by means of a specially constructed vitallium appliance called the K splint

Twenty six patients have been operated upon according to the above method

The final results have been evaluated both anatomically and functionally in seven cases characterized as excellent in six cases as good in four cases as fair and in six cases as poor The approximate functional impairment of the total number of cases is about 77 per cent

The authors of this article conclude that the results achieved through the method described justify further work with the method

RESUME

Cet article décrit une methode elaboree pour prevenir ou corriger une *deformite finale du radius apres lesion provenant d'une fracture* La methode se base sur le principe de la restauration des conditions anatomiques par greffe osseuse combinee a une fixation interne des fragments au moyen d'un dispositif en vitallium specialement construit appele eclisse K 26 malades ont ete operees par cette methode

Les resultats finaux ont ete caracterises au double point de vue anatomique et fonctionnel comme excellents dans sept cas bons dans six cas passables dans quatre cas et mauvais dans six cas L'affaiblissement fonctionnel a ete approximativement de 77 per cent si l'on considere le nombre total des cas

Les auteurs de l'article arrivent a la conclusion que les resultats obtenus par la methode decrite justifient la poursuite des travaux avec cette methode

ZUSAMMENFASSUNG

Diese Arbeit beschreibt eine Methode die entwickelt wurde um eine endgültige Deformitet des Radius nach Bruchschaden zu verhindern oder zu korrigieren Die Methode ist auf dem Prinzip der Wiederherstellung anatomischer Verhältnisse mittels Knochenverpflanzung kombiniert mit einer internen Fixation der Fragmente mittels einer speziell konstruierten Vitalliumschiene genannt K Schiene gegründet 26 Fälle sind durch diese Methode operiert worden

Die Endresultate wurden sowohl anatomisch als auch funktionell bewertet und sieben Fälle wurden als ausgezeichnet sechs Fälle als gut vier Fälle als mittelmässig und sechs Fälle als schlecht angesehen Die ungefähre funktionelle Herabsetzung der Gesamtanzahl der Fälle ist 77 per cent

Die Verfasser dieser Arbeit schliessen dass die mit der beschriebenen Methode erreichten Ergebnisse weitere Verwendung der Methode rechtfertigen

REFERENCES

- Bacon R W & Kurtzke J F (1953) A study of two thousand cases from The New York State Workmens Compensation Board *J Bone Jt Surg* 35 A 643-658
- Campbell W C (1937) Malunited Colles fractures *J Amer med Ass* 109 1105-1108
- The Committee on Medical Rating of Physical Impairment (1958) A guide to the evaluation of permanent impairment of the extremities and back *J Amer med Ass* spec ed. Febr
- De Palma A E (1952) Comminuted fractures of the distal end of the radius healed by ulnar pinning *J Bone Jt Surg* 34 A 651-662
- Durman D C (1937) Discussion of paper of Willis C Campbell on malunited Colles fractures *J Amer med Ass* 109 1108
- Madsen E (1949) Behandling av fractura radii *Nord Med* 41 1134-1137
- Nissen Lie H (1939) Fractura radii typica *Nord Med* 1 293-303
- Rosen H (1947) Fractura extremitatis distalis radii *Ugeskr Læger* 109 603-610
- Rusk I V M D (1954) Closed medullary pinning of Colles fracture *Clin Orthop* 8 157-162
- Wieland T & Mullern Aspegren J (1956) Typisk radiusfractur *Nord Med* 56 1411-1416

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THE POSSIBLE IMPORTANCE OF THE PSOAS MUSCLE FOR STABILIZATION OF THE LUMBAR SPINE

By

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Received 24 XII 67

By intravital discometry it is possible to calculate the load on a particular lumbar disc. This load is correlated to the weight of the subject and the position of the body (21-24).

In the forward stooping and weight lifting positions the results were lower than those theoretically calculated by earlier investigators (19-25-30) but more in agreement with knowledge of the ultimate strength of the vertebral bodies (5-10-14-16-26-28) (Table 1).

In the upright standing and sitting positions however the measurements showed that the discs have to carry relatively high loads (21-24). It is the purpose of this paper to discuss these findings with special reference to the stabilizing function of the vertebral portion of the psoas muscle.

ELECTROMYOGRAPHIC INVESTIGATIONS

Many authors have demonstrated that in the upright positions the sacrospinalis group of muscles are inactive (1-6-12-15-19-20-23-27) but since the body in these positions swings somewhat occasional bursts of activity were noted in long term studies by *Boman & Jalavisto* (3). On forward leaning these muscles increase their activity (12-20-23).

The abdominal muscles were investigated by *Floyd & Silver* (11) and it was found that they too were for all practical purposes inactive in these positions with the exception of some slight activity in the internal oblique muscle.

The vertebral portion of the psoas muscle has received little interest and hardly any reports on its function for the spine are found in the literature (18). *Close* (7) and *Basmajian* (2) investigated the muscle

Table 1 Approximate load in kg on the third lumbar disc in different positions in individuals of varying bodyweights

Weight of subject (kg)	50	60	70	80	90	100
Position of body	load on the disc (kg)					
Upright sitting un supp	110	126	142	158	174	190
Upright standing	73	87	101	111	123	135
Reclining (lateral decubitus)	55	63	71	79	87	93
Reclining (relaxed supine)	15	15	20	20	25	25
Sitting + forward tilting of 20	145	163	191	214	237	260
Sitting + forward tilting of 20 and 10 kg load in each hand	226	249	270	295	317	340
Standing + forward tilting of 20	110	129	148	167	186	205
Standing + forward tilting of 20 and 10 kg load in each hand	177	195	215	234	262	287

with needle electrodes near the hip joint in order to elucidate its action on this joint. Recently an investigation was performed (23) by which it was demonstrated that the psoas muscle showed electromyographic activity in the upright sitting and upright standing positions (Figures 1 and 2). It was also noted that in the standing position the activity increased when leaning forward 20° (Figures 2C and D). In the sitting position there was no such increase while leaning forward but the activity while sitting upright was higher than that when standing upright (Figures 1C and D). This can be explained by the finding that in the upright sitting position the lumbar spine is somewhat flexed in comparison to the upright standing position (29-31).

THE LINE OF GRAVITY

According to previous investigators (1, 4, 8, 9, 29, 31) the line of gravity falls in most subjects through the center of the third lumbar disc in the upright standing position and about 4 cm in front of the center of the disc in the upright sitting position. Thus muscular or ligamentous forces or both must be taken into consideration to explain the relatively high loads found in these positions by intravital discometry.

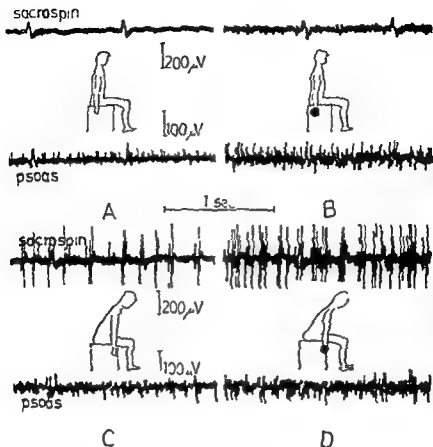


Figure 1 The electromyographic activity of the vertebral portion of the psoas major muscle right side in a male age 24 years A) upright unsupported sitting B) upright unsupported sitting 10 kg in each hand C) sitting and forward leaning in only degrees by flexion in the hip joints D) sitting and forward leaning in only degrees by flexion in the hip joints and holding 10 kg in each hand The electromyographic activity of the sacrospinalis muscles is also shown in the different postures

since gravity alone would give less load. In a man who weighs 70 kg about 40 kg is the weight of the part of the body above his third lumbar disc according to Ruff (28) (Table 2).

THE STABILITY OF THE SPINE

The spinal column which serves as a sustaining rod for the maintenance of the upright position of the body was considered by Lucas

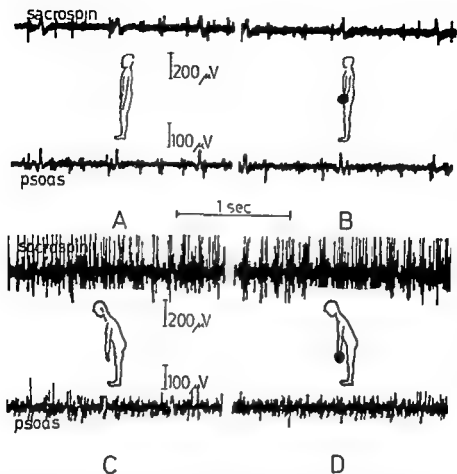


Figure 2 The electromyographic activity of the vertebral portion of the psoas major muscle right side in a male age 25 years A) upright standing at ease B) up right standing 10 kg in each hand C) standing and forward leaning twenty degrees by flexion in the hip joints D) standing and forward leaning twenty degrees by flexion in the hip joints and holding 10 kg in each hand The electromyographic activity of the sacro spinalis muscles is also shown in the different positions

& Bresler (17) to have both an intrinsic and an extrinsic stability. Intrinsic stability is provided by ligaments and discs which bind together the alternating vertebral bodies while extrinsic stability is provided by the paraspinal and trunk muscles.

Considered alone the spinal column and its ligaments behave like a modified elastic rod. When it is fixed at the base its critical load—the greatest load it can sustain without buckling—is only 2 kg (17). Therefore the stability of the spine in the living human being is due

Table 2 Approximate formulas for load (P) on lumbar discs in different positions

Position		
Upright sitting with arms and back unsupported	$P_{\text{sitt}} = P_0 + 28 W$	$P_0 \approx 30 \text{ kg}$
Upright standing	$P_{\text{stand}} = P_0 + 21 W$	$P_0 \approx 15 \text{ kg}$
Reclining (tilted on side lateral decubitus)	$P_{\text{recl}} = \frac{P_0 + 28 W}{2}$	$P_0 \approx 30 \text{ kg}$
Reclining (relaxed supine)	$P_{\text{recl}} = P_0$	$P_0 \approx 15 \text{ kg}$
Sitting + forward leaning α degrees	$P_{\text{sitt}} = P_0 + 28 W + 36 W \sin \alpha$	$P_0 \approx 30 \text{ kg } \alpha = 10^\circ$
Standing + forward leaning α degrees	$P_{\text{stand}} = P_0 + 21 W + 36 W \sin \alpha$	$P_0 \approx 15 \text{ kg } \alpha = 10-20^\circ$

P_0 = intrinsic pressure W = weight above the level measured (59 per cent of bodyweight above L IV 57 per cent above L III and 53 per cent above L II)

pendent on the extrinsic support provided by the trunk muscles. The lack of inherent intrinsic stability of the vertebral column and the importance of the trunk muscles are clearly demonstrated if one tries to hold an unconscious person upright.

DISCUSSION

Intravital discometry has demonstrated that the load on the middle lumbar discs varies with the position of the subject and weight of the body (21-24). The results of these measurements are summarized in Tables 1 and 2.

It is unlikely that gravitation forces are sufficient to explain the relatively high loads in both upright standing and sitting positions found from these measurements.

Previous electromyographic investigations on the activity of the sacrospinalis and anterior abdominal muscle groups demonstrated that all these are with few occasional exceptions inactive in these positions (1, 3, 8, 11, 12, 15, 19, 20, 23, 27, 29).

On the other hand it was recently demonstrated that activity existed in the upright positions in the vertebral portion of the psoas muscle

(23) This muscle should then be considered in providing some of the stability of the lumbar spine. By its activity it also increases the load on the discs in these positions.

Lucas & Bresler (17) demonstrated that ligamentous forces are too small to provide the necessary stabilization and discometry in anesthetized individuals resulted in pressure values corresponding to a load of about 30 kg. This is the magnitude of force that could result from tension in the ligaments. This verified Peltier's (26) and Nachemson's (22) findings on autopsy material.

With our present knowledge it is possible to approximate the amount of force which the vertebral portion of the psoas muscle compresses the lumbar spine in some positions.

If we first consider the load on the lumbar disc in the upright standing position it can be expressed by the following equation (Table 2)

$$\text{eq (1)} \quad P_{\text{standing}} = 15 + 2.1W$$

where W is the bodyweight above the lumbar disc measured and corresponds to the intrinsic load that force resulting from the ligaments. When the body is in equilibrium in the upright standing position there is only occasional activity in the sacrospinalis muscles (15, 27) while the activity of the psoas muscle seems less variable (23).

When standing the line of gravity falls through the center of the third lumbar disc (4, 9) and the force by which the psoas muscles (P_{psoas}) compress this disc in a man of 70 kg thus can be calculated using the above mentioned equation (1). In this case $W = 40$ kg, $P_{\text{standing}} = 99$ kg and thus

$$\text{eq (2)} \quad P_{\text{psoas}} = P_{\text{standing}} - W - 15 = 99 - 40 - 15 = 44 \text{ kg}$$

The bodyweight is calculated according to Ruff (28) who stated that 59 per cent of the bodyweight is above L-4 and 57 per cent above L-3.

Activity in the sacrospinalis group of muscles which probably occurs when the center of gravity moves forward due to swaying (3) will lessen the force by which the psoas muscles compress the disc.

In the upright unsupported sitting position the load on the third lumbar disc in a 70 kg man is 142 kg according to Tables 1 and 2. In this position some light activity was found in the sacrospinalis group of muscles in most cases by Schoberth (29) but only in exceptional cases by Nachemson (23) and Åkerblom (31). The distance from the midpoint of the nucleus pulposus to the midpoint of the attachment of the back muscles is approximately 5 cm according to Warris (30).

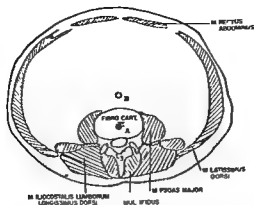


Figure 3 Schematic drawing of the vertebral portion of the psoas major muscle and its relation to the third lumbar disc. The line of gravity in the standing position probably falls through the center of the disc (A). In the upright unsupported sitting position this line falls in front of the center of the disc (B).

and Perey (20). The line of gravity falls about 4 cm in front of the nucleus of the disc (4, 8, 31). If we assume that the midpoint of the psoas attachment is 15 cm behind the center of the disc (Figure 3), the force derived from the activity of the psoas muscle (P_{psoas}) and of the sacro-spinalis muscles (P_{sacro}) can be calculated from the following equations:

$$\text{eq (3)} \quad P_{\text{psoas}} + P_{\text{sacro}} + W = P_{\text{sitting}} - P_0$$

$$\text{eq (4)} \quad P_{\text{psoas}} a_1 + P_{\text{sacro}} a_2 = W a$$

if $a_1 = 15 \text{ cm}$, $a = 5 \text{ cm}$, $a_2 = 4 \text{ cm}$ (Figure 4), $W = 40 \text{ kg}$ and $P_0 = 30 \text{ kg}$ then

$$P_{\text{psoas}} + P_{\text{sacro}} = 142 - 40 - 30 = 72$$

$$15 P_{\text{psoas}} + 4 P_{\text{sacro}} = 160$$

$$P_{\text{psoas}} \approx 58 \text{ kg} \quad P_{\text{sacro}} \approx 15 \text{ kg}$$

In some subjects no activity was found in the sacro-spinalis group of muscles (23, 29). According to the eq (3) the compressive force exerted by the psoas muscles then amounts to 72 kg. In these cases the line of gravity will tend to move closer towards the center of the disc and according to eq (4) this line will now fall only 2.7 cm in front of the center of the disc instead of 4 cm as in the example given above. From these examples it should be clear that if the line of gravity is located 2 cm or 4 cm in front of the center of the disc the compressive

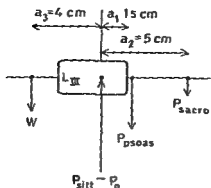


Figure 4 Schematic drawing of the forces and lever arms around the center of the third lumbar disc in the upright sitting position

- W = Body weight above the disc
 P_0 = The intrinsic load on the disc
 P_{sacro} = Force derived from activity of the sacro spinalis muscles
 P_{psoas} = Force derived from activity of the psoas muscles
 P_{sitt} = Total load on the disc in the sitting position
 a_1 = distance from center of psoas muscles to center of disc
 a_2 = distance from sacro spinalis muscles to center of disc
 a_3 = distance from line of gravity to center of disc

force of the sacro spinalis muscles (P_{sacro}) is small in comparison to that of the psoas muscle (P_{psoas})

At the third lumbar level the crosssectional surface area of the psoas muscle is nearly 25 cm² (Figure 3). According to Micheli (18) it is a unipennate muscle which is able to develop a force of between 8 and 10 kg/cm (Hettinger (13)).

With this knowledge in mind the above mentioned figures for the compressive force exerted by psoas muscles in the upright standing and sitting positions fall within reasonable limits.

It should be remembered however that these compressive forces vary somewhat since occasional activity in both the sacro spinalis and anterior abdominal muscles are registered.

SUMMARY

In the upright sitting and standing positions the lumbar spine must be stabilized by extrinsic forces since it has been demonstrated that the intrinsic ones are inadequate.

It is possible that this stabilization in the upright positions is provided to some, probably a major extent by the vertebral portions of

the psoas muscles. It can be calculated that in upright standing this force is about 40 kg and in upright sitting about 60 to 70 kg. In both examples possible activity in the sacro spinalis group of muscles will tend to diminish the forces exerted by the psoas muscles.

RESUME

Dans les positions assise redressee et debout la colonne lombaire doit etre stabilisee par des forces extrinseques puisqu'il a ete demontre que les forces intrinseques sont inadequates.

Il est possible que la stabilisation dans les positions redressees est assuree par une extension probablement majeure des portions vertebrales des muscles psoas.

On a calcule qu'en position redressee il faut une force d'environ 40 kg et en position debout entre 60 et 70 kg. Dans les deux exemples une activite eventuelle du groupe des muscles sacro spinalis tend a diminuer les forces exercees par les muscles psoas.

ZUSAMMENFASSUNG

In der aufrechten sitzenden und stehenden Haltung muss die Lendenwirbelsaule von ausseren Krafte stabilisiert werden, da es sich erwiesen hat, dass die inneren Krafte nicht hinreichend sind.

Es ist moeglich, dass diese Stabilisierung in aufrechter Haltung zu einem wahrscheinlich grosserem Ausmasse von dem vertebraelen Anteil des m. psoas besorgt wird. Man kann berechnen, dass diese Kraft bei aufrechtem Stehen ungefaehr 40 kg und beim aufrechten Sitzen ungefaehr 60 bis 70 kg betraegt. Bei beiden Stellungen wird eine moegliche Aktivitaet der sacro spinalen Muskelgruppe die Neigung haben, die von den Psoasmuskeln ausgeubten Kraft zu vermindern.

REFERENCES

1. Asmussen E. & Klausen K. (1967) Form and function of the erect human. *Clin orthop* 23: 55-63.
2. Basmatjian J. V. (1953) Electromyography of iliopsoas. *Anat Rec* 113: 127-132.
3. Boman K. & Jalavisto E. (1953) Standing steadiness in old and young persons. *Ann Med exp biol Fenn* 31: 447-455.
4. Braune W. & Fischer D. (1889) Ueber die Lage des Schwerpunktes des menschlichen Koerpers. Vol. XX. *Abh Math Phys Klasse d kgl. Sachsen Ges d Wiss Leipzig* 8: Hirzel.

- 5 Brown T Hansen R J & Yorra A J (1957) Some mechanical tests on the lumbosacral spine with particular references to the intervertebral discs *J Bone Jt Surg* 39A 1135-1164
- 6 Carlsoo S (1961) The static muscle load in different work positions. An electromyographic study *Ergonomics* 4 194-211
- 7 Close J R (1964) Motor function in the lower extremity. Charles C. Thomas Springfield Illinois
- 8 Dempster W T (1958) Analysis of two handed pull using free body diagram *J appl Physiol* 13 469-480
- 9 Dempster W T (1955) Space requirements of the seated operator WADC Technical Report 55 159
- 10 Evans F G & Lissner H R (1959) Biomechanical studies on the lumbar spine and pelvis *J Bone Jt Surg* 41A 278-290
- 11 Floyd W F & Silver P H S (1950) Electromyographic study of patterns of activity of the anterior abdominal wall muscles in man *J Anat* 84 137-145
- 12 Floyd W F & Silver P H S (1955) The function of the erectores spinae muscles in certain movements and postures in man *J Physiol* 129 184-203
- 13 Hettinger T (1964) Isometrisches Muskeltraining Georg Thieme Verlag Stuttgart
- 14 Hirsch C & Nachemson A (1961) Clinical observations on the spine in ejected pilots *Acta orthop scand* 31 135-145
- 15 Joseph J (1960) Man's posture. Electromyographic studies. Charles C Thomas Publisher Springfield Illinois
- 16 Laurell L & Nachemson A (1963) Some factors influencing spine injuries in seat ejected pilots *Aerospace Med* 34 726-729
- 17 Lucas D B & Bresler B. Stability of the ligamentous spine. Biomechanics Laboratory Technical Report No 40 Dec 1960 University of California, San Francisco U.S.A
- 18 Michele A A (1962) Iliopsoas. Charles C Thomas Publisher Springfield Illinois
- 19 Morris J M Lucas D B & Bresler B (1961) Role of the trunk in stability of the spine *J Bone Jt Surg* 43A 327-351
- 20 Morris J M Benner G & Lucas D B (1962) An electromyographic study of the intrinsic muscles of the back in man *J Anat* 96 509-520
- 21 Nachemson A & Morris J M (1964) In vivo measurements of intradiscal pressure *J Bone Jt Surg* 46A 1077-1090
- 22 Nachemson A (1963) The influence of spinal movements on the lumbar intradiscal pressure and on the tensile stresses in the annulus fibrosus *Acta orthop scand* 33 183-207
- 23 Nachemson A (1966) Electromyographic studies on the vertebral portion of the psoas muscle *Acta orthop scand* 37 177-190
- 24 Nachemson A (1966) The load on lumbar discs in different positions of the body *Clin orthop* 45 107-122
- 25 Perev M (1957) Fracture of the vertebral end plates in the lumbar spine. An experimental biomechanics investigation. *Acta orthop scand* Suppl 25

26. Petter C. K. (1933) Methods of measuring the pressure of the intervertebral disc *J Bone Jt Surg* **15** 365-368
27. Portnoy H & Morin F (1956) Electromyographic study of postural muscles in various positions and movements *Amer J of Physiol* **186** 177-126
28. Ruff H (1950) Brief acceleration Less than one second. In *German Aviation Medicine World War II* Washington D.C., US Government Printing Office **1** 584-597
29. Schoberth H (1969) *Sitzhaltung Sitzschaden Sitzmöbel* Springer Verlag Berlin
30. Watis W (1948) Lumbar disc herniation Clinical studies and late results of 374 cases of sciatica *Acta chir scand* Suppl. 140
31. Aherblom H (1949) Standing and sitting position AB Nordiska Bokhandeln Stockholm.

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IN VITRO INCORPORATION OF S³⁵ SULFATE IN CHONDROSARCOMATOUS TISSUE

By

HARRY BOSTRÖM¹, ULF FRIBERG¹ & SUNE LARSSON²
& ULF NILSSON²

Received 3.11.67

INTRODUCTION

Radical surgery is at present the only appropriate form of therapy for chondrosarcoma (Dahlin & Henderson 1956). Non radical surgery leads to relapse and radiotherapy is without significant effect. Since chondrosarcomas are most often localized in the proximal part of the femur in the pelvis or in the proximal part of the humerus surgery must be performed as disarticulation, hemipelvectomy or forequarter amputation. The results seem to justify such measures: a 56 per cent 15 year cure rate has been reported for chondrosarcomas of the extremities (Hänelius & Hjelmstedt 1964) and a 30 per cent 10 year cure rate after hemipelvectomy for chondrosarcoma of the pelvis (Troup & Bickel 1960).

While radical surgery is thus relatively successful it obviously creates new problems for the patient. Hence efforts must be made to obviate the necessity of major amputations through the development of new forms of treatment which in turn may require the elaboration of new diagnostic methods. However a more comprehensive knowledge of the biochemistry and metabolism of chondrosarcoma is a prerequisite condition for such attempts.

Financial support was obtained from the Swedish Medical Research Council, King Gustav V 80th Birthday Fund, the Knut and Alice Wallenberg Foundation and the Association for the Aid of Crippled Children, New York. A preliminary account of this work was given at the Annual Meeting of the Swedish Orthopaedic Association, Nov. 25-27 1965, Stockholm, Sweden.

A characteristic feature of chondrosarcomata is the formation of an abundant matrix which as in normal cartilage contains sulfated glycosaminoglycans¹. The biosynthesis of such compounds has been studied intensively in recent years thus the various enzymes and precursors involved are known in some detail as reviewed elsewhere (Boström & Roden 1965).

From a therapeutic standpoint there are here two methods of attack. First an attempt to retard the growth of a chondrosarcoma by interfering with the formation or maintenance of its matrix. For instance several substances are known to have an inhibitory effect on the biosynthesis of sulfated glycosaminoglycans viz cortisone, salicylates, phenylbutazones and anti-malarials (Boström, Bernitsen & Whitehouse 1964). Furthermore it has been shown that parenteral administration of papain can cause the breakdown of the ground substance of preformed cartilaginous matrices (Thomas 1956).

Second the exploitation of the pronounced anabolic activity of the tumor cells in order to introduce a precursor which when built into the sulfated glycosaminoglycans would cause damage to these cells. This approach was used by Gottschalk *et al* (1959), Gottschalk (1960), Andrews *et al* (1960) and Bolstein & Marcus (1963) who administered S³⁵ sulfate to patients with advanced chondrosarcoma for internal irradiation of the tumor tissue. The radio isotope was given in amounts of 0.6–1.2 C. With this dosage temporary arrest of growth and relief of pain was noted in several cases. That high doses of S³⁵ sulfate have a definite radiotoxic effect on growing cartilage is evident from studies on rats (Rubin *et al* 1957) and on mice (Gottschalk & Beers 1958).

These therapeutic trials were based on tracer studies which included autoradiography of biopsy material and demonstrated a preferential uptake of the isotope by the tumor tissue. It was also established that the limiting factor in the therapeutic use of S³⁵ is the radiosensitivity of the hematopoietic system. Marked depression of bone marrow activity invariably followed the administration of the large doses of S³⁵ employed. However the marrow function was completely restored in about a month. Consequently the possibility of multiple courses of S³⁵ treatment for patients who respond well was suggested by Bolstein & Marcus (1963) and is currently being explored in a case with lung metastases (Boström *et al* unpublished observations).

¹ In this paper we have adopted the nomenclature used in *The Amino Sugars* (eds E. A. Balazs & R. W. Jeanl) Academic Press, New York 1963).

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IN VITRO INCORPORATION OF S^{35} SULFATE IN CHONDROSARCOMATOUS TISSUE

By

HARRY BOSTROM¹, Ulf FRIBERG, & SUNF LARSSON
& ULF NILSSON²

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INTRODUCTION

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Financial support was obtained from the Swedish Medical Research Council, King Gustav V 80th Birthday Fund, the Ernst and Alice Wallenberg Foundation and the Association for the Aid of Crippled Children, New York. A preliminary account of this work was given at the Annual Meeting of the Swedish Orthopaedic Association, Nov. 25-27 1965, Stockholm, Sweden.



Figure 1 Case 1 Roentgenogram showing chondrosarcoma in the proximal part of the left femur



Figure 2 Case 2 Roentgenogram showing chondrosarcoma of the proximal part of the left humerus extending into the soft parts of the axilla

Sampling of Tumor Tissue

Each long bone was sawed in two longitudinally and the cut surfaces photographed. One half of each bone was used for histologic diagnosis and radioisotope studies respectively. For these studies tissue blocks were cut from the tumors *in situ*. The blocks measured approximately $5 \times 5 \times 11$ mm and were taken from macroscopically different areas of the tumors as indicated in Figures 3 and 4.

From the tumor in case 1 four blocks were taken designated A-D. In case 2 three blocks were sampled (A-C). For control blocks of articular cartilage were also taken from each bone and were marked E and D respectively.

Incubation

Before incubation each tissue block was cut into two parts, one for biochemical investigation and the other for autoradiography. Each of these parts was subdivided into slices approximately 0.5 mm which were incubated for two hours in 5 ml of a Krebs Ringer solution containing $100 \mu\text{C}$ of radioactive sulfate. After incubation the process was stopped by addition of 1 ml of 2 per cent monoiodoacetic acid. The slices were then carefully washed with water and excess of unlabelled sodium sulfate according to Rostrum *et al.* (1953).

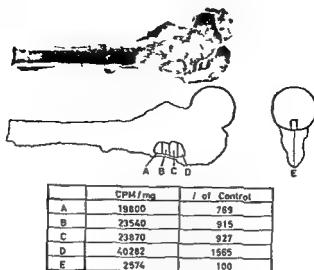


Figure 3 Case 1 Incorporation of S^{35} sulfate (total glycosaminoglycan fraction) into various zones of the tumor (A-D) and into normal joint cartilage (E = control) Radioactivity expressed as counts per minute per mg dry tissue

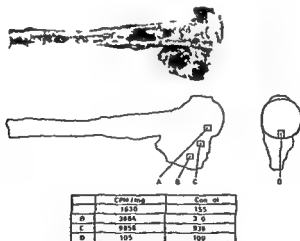


Figure 4 Case II Incorporation of S^{35} sulfate (total glycosaminoglycan fraction) into various zones of the tumor (A-C) and into normal joint cartilage (D = control) Radioactivity expressed as counts per minute per mg dry tissue

Biochemical Analyses and Radio Assays

The slices for examination were further washed in alcohol and ether and dried *in vacuo* weighed on a Cahn micro balance and digested with papain. Complete solubilization of the material was obtained.

From all the digested samples aliquots were taken for indirect determination of

S³⁵ sulfate incorporation into the total glycosaminoglycan fraction The radioactivity of the aliquots was measured before and after precipitation with ethanol and subsequent centrifugation the difference between the two measurements was regarded as representing the S³⁵ activity of the total glycosaminoglycan fraction

The digested samples from case 1 were utilized also to evaluate the incorporation of the isotope into individual glycosaminoglycan fractions These were obtained by the micro separation technique of Antonopoulos *et al* (1963) the radioactivity of each resulting fraction was measured

Assays of S³⁵ activity were made on material plated at infinite thinness A Geiger Muller counter with a 19 mg/cm² end window tube was used Radioactivity was expressed as counts per minute per mg of dry tissue

Morphology and Autoradiography

The incubated and washed slices were fixed in alcohol-formalin (3 + 1 parts) and embedded in paraffin Semi serial sections were cut at 2 and 4 microns and mounted on glass slides About half the number of slides were used for staining and the others for autoradiography The following staining procedures were applied hematoxylin and eosin astrablau (Bloom & Kelly 1960) and toluidine blue (0.1 per cent in 70 per cent ethanol)

Coated autoradiograms were prepared by a modification of the Messier & Leblond method (1957) Ilford h5 nuclear emulsion was used diluted with either one part of water (4 micron sections) or four parts of water (2 micron sections) Exposures lasted from one to two days The autoradiograms were developed in Kodak D 19b cover slipped and were examined by light and by phase-contrast microscopy with qualitative evaluation of density Quantification through grain counting was not attempted since the autoradiograms were too dense over the cells for this in spite of the short exposure time a rather high S³⁵ dosage being used for the *in vitro* incubations to ensure an adequate level of activity for the C.M. counting particularly in the fractionation study

RESULTS

Biochemical analyses and radio-assays

Figures 3 and 4 show the incorporation of radioactive sulfate into the total glycosaminoglycan fraction of the various zones of the tumors and adjacent joint cartilage These figures indicate that the uptake of S³⁵ sulfate was much higher in all tumor samples than in the corresponding samples of normal cartilage but that there were also considerable variations between the samples of an individual tumor Thus the radioactivity of the tumor samples exceeded that of the control cartilage by a factor of about 7 to 15 times in case 1 and of about 1.5 to 9 times in case 2

The results of the fractionation study made in case 1 are summarized in Figure 5 The variation in total radioactivity between the different

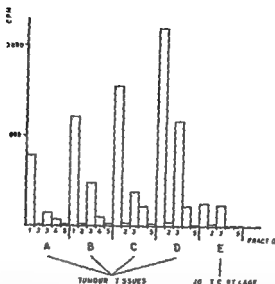


Figure 5 Case 1 Radioactivity in various glycosaminoglycan fractions in tumor tissue (A-D) and into normal joint cartilage (E) Fraction 1 keratan sulfate fraction 2 hyaluronic acid fractions 3 and 4 chondroitin sulfates fraction 5 heparin like compounds

samples essentially parallels that shown in Figure 3. All the tumor samples show a similar distribution pattern of radioactivity between the five fractions. This pattern is distinctly different from that of normal joint cartilage owing mainly to a predominance by a factor of two to five in the radioactivity of fraction 1 over that of fraction 3 but also to the occurrence of significant radioactivity in fraction 4.

Morphology and autoradiography

The histologic examination of the tumors showed that both were rather highly differentiated chondrosarcomas. However, their appearance varied markedly from area to area in respect of both cellularity and character of the matrix. For instance, zones with abundant matrix alternated with clusters of cells (Figure 6 A). The matrix was collagenous in some parts of the tumors and myxomatous in other parts. Formation of chondroid tissue was noted in case 2 (Figure 7 A). Necrotic areas were occasionally observed.

A direct relationship was readily evident between microscopic appearance and uptake of S^{35} sulfate by the tumor samples as determined by G-M counting. The more cellular and the more active the appearance

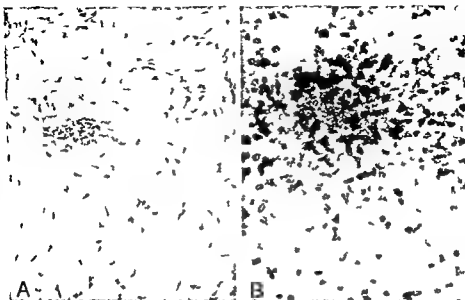


Figure 6 Case 1 A section of the tumor stained with hematoxylin and eosin B coated autoradiogram showing the incorporation of S³⁵ sulfate into a similar area of the tumor $\times 93$

of the sample the higher was its radioactivity. Of the two tumors that in case 1 had the more malignant appearance and showed the most pronounced uptake of the isotope

This correlation between morphology and isotope incorporation was directly visible in the autoradiograms. These show that in both tumor tissue and control cartilage the uptake of S³⁵ sulfate took place as a massive cellular incorporation (Figures 6B, 7B and 8). No uptake of the isotope occurred in necrotic tumor areas.

In the samples of joint cartilage there was no indication of a secretion of S³⁵ labelled matrix components by the chondrocytes. However, in the tumor samples, notably within the cell clusters in case 1, rather dense accumulations of silver grains were also located over the matrix between or immediately surrounding the cells (Figure 6B).

DISCUSSION

An increased *in vitro* uptake of radioactive sulfate into the total glycosaminoglycan fraction by the chondrosarcomatous tissues, as compared with the uptake of the normal joint cartilage, was demonstrated in this



Figure 7 Case 2 A section of the tumor stained with hematoxylin and eosin B coated autoradiogram showing the incorporation of S^{35} sulfate into a similar area of the tumor $\times 90$

investigation. This is in good agreement with earlier observations *in vitro* (Layton 1949 Wolfe & Vickery 1964) and *in vivo* (Gottschalk *et al* 1952 1959 Gottschalk 1960 Andrews *et al* 1960 Rotstein & Marcus 1963).

The greater cellularity of the tumor tissues is a major factor affecting this increased uptake as indicated by the morphologic and autoradiographic findings. Moreover the variations in radioactivity between the different tumor samples were clearly related to cellular content. Conceivably an accelerated turnover may also be involved but this could not be demonstrated with certainty in the present material. Variations in synthetic rate among skeletal cells can in general be detected by autoradiography namely through evaluation preferably by grain counting of the initial incorporation of the isotope into the cells or through observation of the subsequent transfer rate of labelled components to the matrix (see for instance Öberg 1964). The latter procedure requires the harvesting of samples after consecutive time intervals which was not possible in this study because of the limited amount of material available. It has already been mentioned that grain counting was not feasible. Nonetheless the occurrence of silver grains

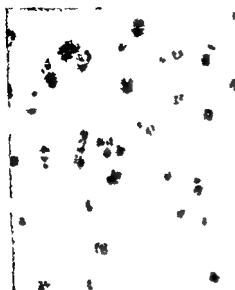


Figure 8 Case 1 Coated autoradiogram showing the incorporation of S³⁵ sulfate into normal joint cartilage $\times 95$

over tumor matrix may be taken as indicating increased synthetic rate compared with that of normal cartilage. These silver deposits may be interpreted as representing a secretion of labelled glycosaminoglycans into the intercellular compartment and/or a more intense emission from the cells.

As far as we are aware no systematic attempt has been made to characterize the glycosaminoglycans in a comprehensive material of chondrosarcomatous tumors. However the occurrence of sulfated glycosaminoglycans has been examined in a few separate cases. Two chondrosarcomata and one chordoma were studied by Meyer *et al* (1956). One chondrosarcoma yielded chondroitin-4 sulfate as the only glycosaminoglycan whereas the other two tumors contained only chondroitin-6 sulfate. Adams (1963) isolated chondroitin-4 sulfate from one chondrosarcoma and demonstrated the absence of keratan sulfate. Previous investigations have thus repeatedly shown that chondroitin sulfates occur in chondrosarcomatous tissue but have failed to disclose the presence of keratan sulfate. It nevertheless seems reasonable to expect also the latter glycosaminoglycan to occur at least in some cases of chondrosarcoma since it too is an important constituent of normal human cartilage. This assumption is supported by the results of the fractionation study in case 1.

In the latter study the tumor samples showed much the same pattern of radioactivity. This indicates that the malignant cells produced a

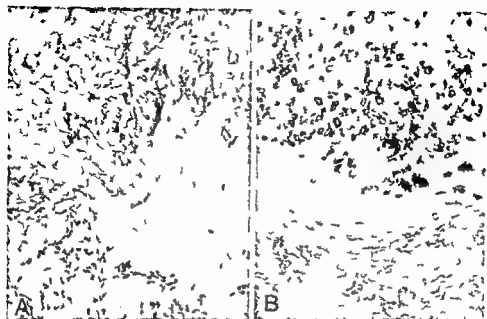


Figure 7 Case 2 A section of the tumor stained with hematoxylin and eosin B coated autoradiogram showing the incorporation of S^{34} sulfate into a similar area of the tumor $\times 30$

investigation. This is in good agreement with earlier observations *in vitro* (Layton 1949 Wolfe & Vickery 1964) and *in vivo* (Gottschalk *et al* 1952 1959 Gottschalk 1960 Andrews *et al* 1960 Bolstein & Marcus 1963).

The greater cellularity of the tumor tissues is a major factor affecting this increased uptake as indicated by the morphologic and autoradiographic findings. Moreover the variations in radioactivity between the different tumor samples were clearly related to cellular content. Conceivably an accelerated turnover may also be involved but this could not be demonstrated with certainty in the present material. Variations in synthetic rate among skeletal cells can in general be detected by autoradiography namely through evaluation preferably by grain counting of the initial incorporation of the isotope into the cells or through observation of the subsequent transfer rate of labelled components to the matrix (see for instance Öberg 1964). The latter procedure requires the harvesting of samples after consecutive time intervals which was not possible in this study because of the limited amount of material available. It has already been mentioned that grain counting was not feasible. Nonetheless the occurrence of silver grains

SUMMARY

The *in vitro* incorporation of S³⁵ sulfate was studied in samples from two surgically removed chondrosarcomas of long bones; samples of adjacent joint cartilage served as controls.

The utilization of the isotope was determined by biochemical analyses made visible by autoradiography and correlated to the morphology of the individual samples.

Incorporation by the tumor samples of S³⁵ sulfate into the total glycosaminoglycan fraction exceeded that of the controls by 7 to 15 times in case 1 and by 1.5 to 9 times in case 2.

Determination of the radioactivity of individual glycosaminoglycan fractions in case 1 showed that a similar spectrum of sulfated glycosaminoglycans was produced in all the tumor samples. Keratan sulfate and chondroitin sulfate(s) were the main constituents. The synthesis of keratan sulfate was greatly accelerated in relation to that of chondroitin sulfate(s).

The autoradiograms showed that the uptake of S³⁵ sulfate was due to a pronounced cellular incorporation both in chondrosarcomatous tissues and in normal cartilage. Variations in cellular content of the tissues was a major factor in causing the differences in the uptake of the isotope between the tumor samples and the control samples and also between individual tumor samples.

The significance is discussed of *in vitro* experiments as a supplement to therapeutic trials with S³⁵ sulfate in cases of chondrosarcoma.

RESUME

L'incorporation *in vitro* du sulfate S³⁵ a été étudiée sur des prélèvements de deux chondrosarcomes d'os long obtenus chirurgicalement. Des spécimens de cartilage articulaire adjacent ont servi de contrôle.

L'utilisation de l'isotope a été déterminée par analyse biochimique rendue visible par autoradiographie et en corrélation avec la morphologie des prélèvements individuels.

L'incorporation dans les prélèvements de la tumeur de sulfate S³⁵ a été effectuée jusqu'à ce que la fraction de glycosaminoglycan dépasse celle des spécimens de contrôle de 7 à 15 fois dans le cas 1 et de 1.5 à 9 fois dans le cas 2.

La détermination de la radioactivité des fractions glycosaminoglycan individuelles dans le cas 1 montre qu'un spectre similaire de glycosaminoglycan sulfate s'est produit dans tous les prélèvements de la

tumeur Des sulfates de kératine ont été les principaux constituants. La synthèse du sulfate de kératine était fortement accélérée par rapport à celle du sulfate de chondroïtine.

Les autoradiographies montrent que l'absorption de sulfate S^{35} est due à une incorporation cellulaire prononcée tant dans les tissus chondrosarcomateux que dans le cartilage normal. Des variations dans le contenu cellulaire des tissus a été un facteur majeur comme cause des variations dans l'absorption de l'isotope entre les différents prélèvements de la tumeur.

Il est discuté de l'importance des expériences *in vitro* comme complément aux essais thérapeutiques avec le sulfate S^{35} dans le cas de chondrosarcome.

ZUSAMMENFASSUNG

Die *in vitro* Einverleibung von S^{35} Sulfat wurde in Proben von zwei chirurgisch entfernten Chondrosarkomen langer Röhrenknochen studiert. Proben von angrenzendem Gelenkknorpel dienten als Kontrollen.

Die Ausnutzung der Isotopen wurde mittels biochemischer Analysen bestimmt. wurde mittels Autoradiographie sichtbar gemacht und in Beziehung zur Morphologie der einzelnen Proben gebracht.

Aufnahme in die Tumorseiten von S^{35} Sulfat in die gesamte Glycosaminoglycan Fraktion überstieg die der Kontrollen 7 bis 15 mal im 1. Falle und 1,5 bis 9 mal im 2. Falle.

Bestimmung der Radioaktivität von einzelnen Glycosaminoglycan Fraktionen in Fall 1 zeigte, dass ein gleichartiges Spektrum von Sulfat Glycosaminoglycanen in allen Tumorseiten erzeugt wurde. Keratinsulfat und Chondroitinsulfat(e) waren die Hauptbestandteile. Die Synthese von Keratinsulfat war im Verhältnis zu der des Chondroitinsulfat(e) sehr beschleunigt.

Die Autoradiogramme zeigten, dass die Aufnahme von S^{35} Sulfat einer ausgesprochenen zellulären Einverleibung zuzusprechen war, so wohl in chondrosarkomatosem Gewebe als auch in normalem Knorpel. Unterschiede im Zellgehalt der Gewebe waren ein grosser Faktor bei der Verursachung der Verschiedenheiten in der Aufnahme der Isotopen zwischen den Tumorseiten und den Kontrollproben und auch zwischen den einzelnen Tumorseiten.

Die Bedeutung der *in vitro* Versuche als eine Ergänzung zu den Behandlungsversuchen mit S^{35} Sulfat in Fällen von Chondrosarkom wird besprochen.

REFERENCES

- Adams J H (1963) Sulfate metabolism in avian and mammalian cartilage extracts
Arch Biochem Biophys 101 478-488
- Andrews J R, Swann R L, Schlachter L, Brace K C, Rubin Ph, Bergenstal D M, Gump H, Siegel S & Swain R W (1960) The effects of one curie of sulfur 35 administered intravenously as sulfate to a man with advanced chondrosarcoma
Amer J Roentgenol 83 123-134
- Antonopoulos C A, Gardell S, Szirmai J A & De Tresson L E R. (1964) Determination of glycosaminoglycans (mucopolysaccharides) from tissues on the microgram scale *Biochim Biophys Acta* 83 1-19
- Bloom G & Kelly J W (1960) The copper phthalocyanin dye Astrablau and its staining properties especially the staining of mast cells *Histochem* 2 48-57
- Bostrom H & Månsson B (1953) Factors influencing the exchange of the sulphate group of the chondroitin sulphuric acid of cartilage *in vitro* *Arkiv Kemi* 6 23-37
- Bostrom H, Friberg U, Odéblad E. & Ringertz N (1954) Uptake of labelled sulphate by experimental skin tumors in the rat and the mouse *Acta path et microbiol scandinav* 35 17
- Bostrom H, Jorpes E, Månsson B, Roden L. & Vestermark, A (1955) On the partial purification of a liver factor stimulating the sulphate exchange of chondroitin sulphuric acid *Arkiv Kemi* 8 469-480
- Bostrom H, Berntsen K. & Whitehouse W W (1964) Studies on ester sulphates. 20 Biochemical properties of anti inflammatory drugs. II Some effects on sulphate 35S metabolism *in vivo* *Biochem Pharmacol* 13 413-420
- Bostrom H & Roden L. (1965) Metabolism of glycosaminoglycans in "The Amino Sugars" Vol II B Eds Fudré A, Balazs and Roger W Jeanloz Academic Press New York, p 45-80
- Bolstein C. & Marcus N (1963) A case of recurrent chondrosarcoma of the maxilla treated unsuccessfully with sulphur 35 *Amer J Roentgenol* 80 555-558
- Dahlin H C & Henderson E. D (1956) Chondrosarcoma. A surgical and pathological problem *J Bone Jt Surg* 38A 1025-1038
- Gottschalk R G & Allen H C Jr (1952) Uptake of radioactive sulfur by chondrosarcomas in man *Proc Soc exp Biol Med* 80 334-339
- Gottschalk R C & Beers H N (1953) Selective toxicity of radioactive sulfate for mouse cartilage and bone marrow *1954 Arch Path* 63 298-311
- Gottschalk, R C, Alpert L. K. & Alpert H. F (1959) The use of large amounts of radioactive sulfur in patients with advanced chondrosarcomas. I Clinical and hematologic observations *Cancer Res* 19 1070-1077
- Gottschalk R. C., Alpert L. K. & Miller Ph O (1959) The use of large amounts of radioactive sulfur in patients with advanced chondrosarcomas. II Distribution and tissue irradiation *Cancer Res* 19 1018-1035
- Gottschalk, R G (1960) Radioactive sulphur in chondrosarcomata *J Bone Jt Surg* 42 A 1939-1957
- Haakelius A & Hjelmstedt A (1964) Behandling resultatene vid chondrosarkom *Nord Med* 70 1033-1034
- Layton L. L. (1949) Labelled inorganic sulfate in the diagnosis of cartilaginous tumors and their metastases *Cancer* 2 1059-1092

- Lavton L. L. (1956) *In vitro* sulfate fixation by granulation tissue and injured muscle tissue from healing wounds *Proc Soc exp Biol Med* 73 370-372
- Messier H & Leblond C. P. (1957) Preparations of coated radioautographs by dipping sections in fluid emulsion *Proc exp Biol Med* 96 7
- Meyer K, Davidson E. A., Linker A & Hoffman P. (1956) The acid mucopolysaccharides of connective tissue *Biochim biophys Acta* 21 506-518
- Meyer K, Hoffman P. & Linker A. (1958) Mucopolysaccharides of costal cartilage *Science* 128 895
- Öberg T. (1964) Morphology, growth and matrix formation in the mandibular joint of the guinea pig *Trans Roy Soc Dent* 10
- Rubin P, Brace K. C., Gump H, Swann H & Andrews J. R. (1957) The radiotoxic effects of S^{35} in growing cartilage. *Radiology* 69 711-719
- Thomas L. (1956) Reversible collapse of rabbit ears after intravenous papain and prevention of recovery by cortisone *J exp Med* 104 245-252
- Troup J. B. & Bickel W. H. (1960) Malignant disease of the extremities treated by exarticulation. Analysis of two hundred and sixty four consecutive cases with survival rates *J Bone Jt Surg* 42 A 1041-1050
- Wolfe H. J. & Vickery A. L. (1964) The use of S^{35} labeled sulfate in studies on human normal and neoplastic cartilage tissues *Lab Invest* 18 743-751

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A CASE OF TRAUMATIC MYOSITIS OSSIFICANS IN THE ILIOPSOAS MUSCLE

By

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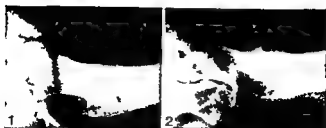
Traumatic myositis ossificans is a rare disease and it is very unusual for it to affect the iliopsoas muscle. In the case to be reported below it resulted in very annoying limitation of movement in the hip.

CASE REPORT

A woman aged 43 with no major illnesses injured her hand in a lawn mower. Nine days later she developed tetanus and was kept under anaesthesia for 25 days. After the anaesthesia she woke up with a painful left hip in which the movements were highly restricted. The complaints due to the hip prevented her from sitting normally, made it difficult to dress, hardly allowed a normal sex life and at last resulted in a serious depression.

At the end of about 3 months she was admitted to the Department of Physical Medicine T, University Hospital, Copenhagen. There was some atrophy of the left thigh and gluteal region. The left hip was contracted in 20° flexion and 30° external rotation and it was doubtful whether the joint permitted any movement at all. Attempts at moving the joint gave rise to pain and the patient felt pain when sitting and when walking which she could do however without a limp. Deep to the inguinal ligament palpation revealed a firm, tender, ill-defined area. X-rays demonstrated a calcific shadow 10 cm in length from the neck of the femur towards the lesser trochanter. The calcific shadow was about 1 cm from the bone (cf. Figure 1).

The patient was referred for orthopaedic examination which also indicated myositis ossificans in the lower part of the iliopsoas muscle. The orthopaedists advised against removal of the ossified area, stating that empirically its removal often gives rise to further ossification. The patient was treated for a few weeks with exercises and was given a few injections of corticosteroids with local anaesthetic added. She was discharged and seen in the out-patient department 1 month later. The condition of the hip was unchanged and so was her mental depression. She was advised to consult John Charnley, chief orthopaedist in a centre for hip surgery at the Wrightington Hospital in England. Three months later Mr Charn



ley wrote that he had removed a localized mass of tissue affected with myositis ossificans and that 4 days after the operation there was almost free mobility of the left hip. The patient was invited for a follow up examination here about 7 months after operation. She has no subjective complaints from the left hip and apart from an about 20° restriction of flexion there was free mobility without pain. In the sitting position the patient cannot lift her extended left leg indicating a considerably impaired function of the iliopsoas muscle (Ludloff's symptom). However this weakness of the hip flexors on the left is negligible compared with the complaints prior to the operation. X rays showed that the calcific strand anterior to the femoral neck has disappeared while at the lesser trochanter there was a bean sized calcification (Figure 2).

DISCUSSION

The present case represents a rare localization of traumatic myositis ossificans which more often affects the brachial muscle, the quadriceps femoris or the adductor femoris muscles (Bailey & Love 1946, Croh 1962). However a similar case has been published by Aberle Horstnegg (1931). A 35 year old woman overstretched her hip in a fall (into the splits). She developed a large calcified hematoma in the iliopsoas muscle on the anterior aspect of the hip joint. As this caused considerable limitation of movement it was removed 6 months later with a good functional result.

In respect to the treatment of traumatic myositis ossificans Watson Jones (1955) feels that surgery is not indicated until the hematoma around the ossification has been absorbed and spontaneous improvement of mobility in the joint no longer occurs. Bailey & Love (1946) and Bertelsen (1959) state that excision to healthy tissue, chiselling off inhibitory bony tissue may be required but that this should not be done until the process has become quiescent.

SUMMARY

A case of traumatic myositis ossificans affecting the iliopsoas muscle is reported.

This lesion caused an extremely annoying limitation of movement in one hip. There is a certain tradition for reserve in applying surgical treatment although several textbooks of general and orthopaedic surgery do emphasize that it is indicated by disabling limitation of movement.

Our patient underwent operation in a centre for hip surgery in England and obtained an excellent functional result.

RESUME

Etude d'une observation de myosite ossifiante traumatique localisee dans le muscle iliopecte. La maladie « entraine une reduction genante de la mobilite de l'une des hanches. Traditionnellement « est une certaine prudence qu'on « recour a la therapie operateure dans les cas de myosite ossifiante bien que plusieurs manuels de chirurgie et d'orthopedie soulignent comme indication d'une intervention une reduction invalidisante de la mobilite provoquee par cette maladie.

Notre malade a ete operee dans un centre de chirurgie de la hanche en Angleterre avec un excellent resultat fonctionnel.

ZUSAMMENFASSUNG

Eine Krankengeschichte mit einer Myositis ossificans die im m. iliopecte lokalisiert war wird durchgegangen. Das Leiden fuhrt zu einer ausserst genierenden Bewegungseinschränkung in einer Hüfte. Es besteht eine gewisse traditionelle Zurückhaltung in der operativen Behandlung der Myositis ossificans obwohl mehrere chirurgische und orthopädische Lehrbücher die Indikation dafür bei invalidisierender Bewegungseinschränkung als eine Folge des Leidens hervorheben.

Unser Patient wurde in einem Zentrum für Hüftchirurgie in England mit ausgezeichnetem funktionellen Resultat operiert.

REFERENCES

1. Aberle Horstenegg W. (1931) Isolierter Abriss der Trochanter minor—Epiphyse und aquivalenter Muskelriss des Iliopsoas. *Zbl. Chir.* 58: 1439–1443.
2. Bailey H., & Love H. J. (1946) *A short practice of surgery*. H. K. Lewis & Co Ltd., London 810–811.
3. Bertelsen A. (1959) *Nordisk lärobok i ortopedi*. Svenska Bokförlaget, Bonniers Stockholm 312.
4. Croh Herbert (1967) *Sportmedizin*. Ferdinand Enke Verlag Stuttgart 1: 5–12.
5. Watson-Jones R. (1955) *Fractures and joint injuries*. E. & S. Livingstone Ltd. Edinburgh and London 4th. ed. vol. 1: 56.

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THE EPIPHYSEAL ANGLE IN COXA VARA INFANTUM AND ITS RELATION TO RESULTS

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Received 25.11.67

Though the primary cause of coxa vara infantum is still obscure, its roentgenological appearance is fairly well defined.

There is general agreement that adequate therapy consists of various types of correction osteotomies.

The purpose of the operation is above all to re-establish pelvic stability and though a certain discrepancy has been described between functional and roentgenological results (Johanning 1951; Magnusson 1954) attempts are always made to obtain a correct roentgenological result. Pylkkanen (1960) found that a good roentgenological result invariably meant a good clinical result as well.

As known, the pathologic anatomy is believed to consist of a disorder of the enchondral ossification of the epiphysis of the femoral head which, owing to decreased strength of the juxta epiphyseal bone of the neck, results in a statically induced coxa vara and sometimes even in loss of continuity in the collum.

It would therefore appear that purely mechanical and dynamic factors play an important role both in the development of the deformities and in the end results of operation.

In 1935 Pauwels published his first work on the effect of the slope of the fracture and thereby of the ratio between the shearing force and the force of compression on the prognosis of collum femoris fractures.—It is tempting to assume that in coxa vara infantum similar mechanical factors are at work and that the angle between the pathological growth zone and the horizontal plane, the epiphyseal angle, may thus be of importance in the development of the secondary varus.

Since 1932 as many as 39 growing hips with coxa vara infantum

have been treated with sub- or intertrochanteric osteotomy at the orthopaedic department in Härnösand. In 50 of these hips the roentgen films allowed measurement of the angle achieved by operation between the epiphyseal line in the caput femoris and the horizontal plane through the γ cartilage—the epiphyseal angle. This measurement (previously used by *Johanning 1952, Jerre 1956, Pyklänen 1960*) was made in roentgenograms taken with the patient supine on the table with the lower extremities extended in neutral position. The collum diaphyseal angle was also measured in films taken at the last roentgen follow up. This angle was measured according to *Müller (1957)*.

The results of these measurements are given in Table 1.

At the time of the operation these patients were on the average 8.6 years old. The mean period of observation was 3 years—There were 26 female and 24 male hips.

It is clear from Table 1 that all the hips with an epiphyseal angle of less than 30° at the post operative roentgen examination showed a collum diaphyseal angle lying within the normal range at the last roentgen follow up.

Pauwels (1935, 1965) showed that when a fracture line in the femoral neck forms an angle of more than 25° with the horizontal plane the shearing force begins to make itself felt while when the angle is smaller the force of functional compression is predominant. The hips in Table 1 with a smaller epiphyseal angle than 30° would thus correspond to *Pauwels* group 1.

Of the hips which postoperatively showed an epiphyseal angle between 30° and 50° and thus corresponded to *Pauwels* group 2, 10 showed a normal diaphyseal angle at the last roentgen control while 7 showed coxa vara (Table 1).

Table 1. Coxa vara infantum. 50 hips treated by sub- or intertrochanteric osteotomy. Roentgenological findings.

Post operative epiphyseal angle	Collum diaphyseal (C-d) angle at review Number of hips	
	(C-d angle normal (115–140°))	Coxa vara (C-d angle < 115°)
< 30	11	
30–50	10	7
> 50		2

Angle between epiphyseal line and horizontal plane

From the Orthopaedic Clinic Harnosand Sweden
(Head N Lindstrom MD)

THE EPIPHYSEAL ANGLE IN COXA VARA INFANTUM AND ITS RELATION TO RESULTS

By

STEFAN HARALDSSON

Received 20.11.67

Though the primary cause of coxa vara infantum is still obscure its roentgenological appearance is fairly well defined

There is general agreement that adequate therapy consists of various types of correction osteotomies

The purpose of the operation is above all to re establish pelvic stability and though a certain discrepancy has been described between functional and roentgenological results (*Johanning 1951 Magnusson 1954*) attempts are always made to obtain a correct roentgenological result *Pylkkänen (1960)* found that a good roentgenological result invariably meant a good clinical result as well

As known the pathologic anatomy is believed to consist of a disorder of the enchondral ossification of the epiphysis of the femoral head which owing to decreased strength of the juxta-epiphyseal bone of the neck results in a statically induced coxa vara and sometimes even in loss of continuity in the collum

It would therefore appear that purely mechanical and dynamic factors play an important role both in the development of the deformities and in the end results of operation

In 1931 *Pauwels* published his first work on the effect of the slope of the fracture and thereby of the ratio between the shearing force and the force of compression on the prognosis of collum femoris fractures —It is tempting to assume that in coxa vara infantum similar mechanical factors are at work and that the angle between the pathological growth zone and the horizontal plane the epiphyseal angle may thus be of importance in the development of the secondary varus

Since 1932 as many as 59 growing hips with coxa vara infantum



Figure 2 Case 27 ♂ Age 8 years



Figure 3 Case 27 ♂ Age 15 years

Figure 3 shows the same patient 7 years later (7 years after first examination). The right collum diaphyseal angle is 127° and the epiphyseal angle 20° — i.e. both normal — Intertrochanteric osteotomy had been done 4 years previously on the left side. Here the collum diaphyseal angle is 88° — thus coxa vara. The postoperative epiphyseal angle of this hip was 65° .

In view of the advancing physiological varization of the collum diaphyseal angle which occurs during the entire period of growth the amount of spontaneous valgization shown in Figures 1 and 2 was in reality larger than what is suggested by the illustrations.

Spontaneous normalization of coxa vara infantum has been reported earlier but judging from the literature it is rare. *Indemann* (1949) reported 2 hips with normalization of the collum diaphyseal angle after conservative treatment. *Jerre* (1956) and *Rull* (1957) described 1 hip each with practically complete restitution without treatment. *Pylkkänen* (1960) reported 4 untreated hips with complete spontaneous recovery.

The investigation appears to justify the conclusion that in coxa vara infantum one should not accept a postoperative epiphyseal angle of

more than 30°. This conclusion is in agreement with the findings of previous workers in this field (Johanning 1951). Though early osteotomy is the standard therapeutic measure, a certain expectative attitude might be adopted in those cases (possibly with attempted valgization by great trochanter epiphysodesis (Laurent 1959, Pyllkänen 1960, Chigot & Labbe 1962)) where the epiphyseal angle does not exceed 30° and the roentgenologic juxta epiphyseal pathologic changes are moderate.

SUMMARY

In a series consisting of 50 growing hips with coxa vara infantum the relation was studied between the postoperative epiphyseal angle and the collum diaphyseal angle at the last roentgen follow up.

All the hips that showed an epiphyseal angle of less than 30° after the operation had a normal collum diaphyseal angle at the last re-examination. The larger the postoperative epiphyseal angle the greater the tendency to coxa vara as an end result.

All the hips with a postoperative epiphyseal angle of more than 50° had a collum diaphyseal angle of less than 115° at the last re-examination.

The material also included 3 conservatively treated hips 4 of them showed an epiphyseal angle of about 30°. All became normal spontaneously. The 5th with an epiphyseal angle of 50° showed an increased varus deformity at the last examination.

RESUME

Dans une série d'observations comprenant 50 hanches avec coxa vara infantum en croissance la relation entre l'angle épiphysaire post-opératoire et l'angle colonne diaphyse au dernier examen radiographique a été étudiée.

Toutes les hanches dans lesquelles l'angle épiphysaire était inférieur à 30° après l'opération avaient un angle colonne diaphyse normal au dernier examen. Plus l'angle épiphysaire post-opératoire est grand plus il en résulte une tendance au coxa vara.

Toutes les hanches ayant un angle épiphysaire post-opératoire de plus de 50° avaient un angle colonne diaphyse de moins de 115° au dernier examen.

Les observations comprenaient aussi 3 hanches soumises à un traitement conservateur. Chez 4 d'entre elles l'angle épiphysaire était d'environ 30°. Toutes devinrent normales spontanément. Dans le 5ème cas

ou l'angle épiphysaire était de 50°, on a constaté au dernier examen une déformation varus plus prononcée

ZUSAMMENFASSUNG

In einer Reihe von 50 Hüften im Wachstumsalter mit Coxa vara infantum wurde die Beziehung zwischen dem postoperativen Epiphysenwinkel und dem Collum Diaphysenwinkel bei der letzten Röntgenuntersuchung studiert

Alle Hüften die einen Epiphysenwinkel von weniger als 30° nach der Operation zeigten hatten einen normalen Collum Diaphysenwinkel bei der letzten Nachuntersuchung. Je grösser der postoperative Epiphysenwinkel war, desto grösser war die Neigung zur Coxa vara als ein Untersuchungsergebnis.

Alle Hüften mit einem postoperativen Epiphysenwinkel von mehr als 50° hatten einen Collum Diaphysenwinkel von weniger als 110° bei der letzten Nachuntersuchung.

Im Material waren auch 5 konservativ behandelte Hüften inbegriffen. 4 derselben zeigten einen Epiphysenwinkel von ungefähr 30°, alle wurden von selbst normal. Die fünfte mit einem Epiphysenwinkel von 50° zeigte eine zunehmende Varusdeformität bei der letzten Untersuchung.

REFERENCES

- Chigot P. L. & Labbe G. (1967) Allongements cervicaux après section du grand trochanter chez l'enfant. *Rev. chir. orthop.* 48: 199-207.
- Haraldsson S. (1964) Epiphysewinkel bei coxa vara infantum. *Nord. Med.* 72: 1087.
- Jerre T. (1956) Spontaneous Recovery in Coxa Vara Infantum. *Acta orthop. scand.* 25: 149-153.
- Johanningh K. (1951) Coxa Vara Infantum. *Acta orthop. scand.* 21: 273-299.
- Johanningh K. (1957) Coxa Vara Infantum. *Acta orthop. scand.* 22: 100-125.
- Lanz T. V. & Wachsmuth W. (1938) *Praktische Anatomie*. J. Springer Berlin.
- Laurent, L. E. (1959) Growth Disturbances of the Proximal End of the Femur in the Light of Animal Experiments. *Acta orthop. scand.* 28: 255-261.
- Lindemann K. (1949) Zur Morphologie der Coxa vara congenita. *Z. Orthop.* 78: 47-67.
- Magnusson H. (1954) Coxa Vara Infantum. *Acta orthop. scand.* 23: 284-308.
- Müller M. E. (1957) *Die hüftnahen Femurosteotomien*. C. Thieme Stuttgart.
- Pauwels F. (1935) *Der Schenkelhalsbruch ein mechanisches Problem*. F. Enke Stuttgart.
- Pauwels J. (1965) *Gesammelte Abhandlungen zur funktionellen Anatomie des Bewegungapparates*. Springer Berlin.
- Sjöblom P. V. (1960) Coxa Vara Infantum. *Acta orthop. scand.* Suppl. 48.
- Rütt J. (1957) *Orthopädie*. W. in Hohmann C. Hackenbroch W. & Lindemann K. *Handbuch der Orthopädie*. 1. Aufl. C. Thieme Stuttgart, 1961.

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ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION BY A VASCULARIZED AND INNERVATED GRAFT

An Experimental Study on Rabbits

By

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Received 22 ix 67

For the reconstruction of the anterior cruciate ligament distally based fascia or tendon grafts (Hey Groves 1917 1920 Verle d Aubigne (according to Ficat 1962) O'Donoghue 1963 Jones 1963) proximally attached tendon grafts (Indemann 1944 Augustine 1954) and even the meniscus (Smillie 1962) are used. Since it is obvious that distally based transplants have lost their blood supply and innervation it may be assumed that they are of no more value than free transplants. On the other hand dynamic ligaments connected with muscle and formed by means of tendon transposition are unphysiological owing to their muscular function.

In the present experimental study we have worked with tendon grafts in which neurovascular element is preserved but the muscular connection is severed, our aim being to see how such a graft behaves when it is transposed intra-articularly to the site of the anterior cruciate ligament.

METHOD

The experimental animals were white rabbits of the same stock and approximately the same age and weight (about 2½ kg). For the study 30 animals were used 7 of which were lost at operation or because of postoperative infection. The rabbits were anaesthetized with intravenously administered Nembutal® (Abbott). Through an anterolateral incision in the left knee the joint was opened and the anterior cruciate ligament removed. The tendon of the semitendinosus muscle was separated from the medial condyle of the tibia and the tendon was tagged with a suture. The origin of the same muscle was separated with a knife from the ischial tuberosity (Figure 1). The purpose was to preserve the circulation and innervation of the muscle tendon

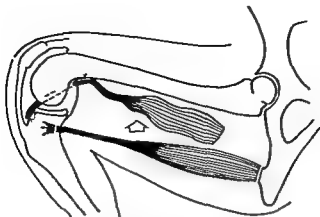


Figure 1 Operation The semitendinosus muscle is freed at both ends The tendon is transposed behind the femur and brought into the knee joint to the site of the excised anterior cruciate ligament

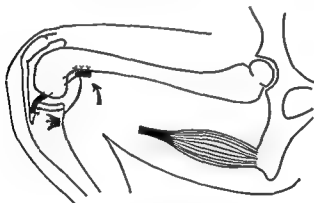


Figure 2 A free graft is taken from the tendon of semitendinosus muscle and fixed to the site of the excised cruciate ligament

unit intact. The posterior capsule of the knee was opened at its femoral insertion and through this opening the freed tendon was pulled as atraumatically as possible through the joint. The distal end of the tendon was fastened to the tibial insertion of the anterior cruciate ligament and thence anteriorly with nylon or steel sutures. In some instances the tendon was attached with superficial sutures to the posterior femoral periosteum. The fate of the vascular system of the muscle was investigated by means of angiography.

For control operations were made in which the same part of the tendon was transplanted as a free graft to the same site as described above but with firm sutures at both ends (Figure 2). In addition ligament construction according to Nev Groves method was carried out in 2 cases (Figure 3). The operated limb was

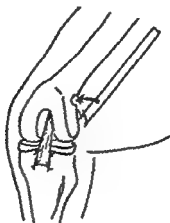


Figure 3 Hey Groves's reconstruction of the anterior cruciate ligament



Figure 4 Immobilizing plaster cast

immobilized with a plaster bandage around the trunk (Figure 4) which was removed after 3 weeks. Some animals tore off the bandage earlier.

The animals were sacrificed after periods of varying length. Angiography of their lower limbs was carried out as follows. The animal was heparinized (*intra vitam*) (200 U Heparin/kg). It was then killed with an intravenous overdose of pentobarbital. The abdominal aorta was exposed, cannulated and injected with Micropaque suspension (1 part Micropaque/2 parts water). Perfusion was continued for 45-90 minutes at a pressure of 80-90 mm Hg. An angiogram was then made of the entire hind part of the animal.

The reconstructed ligament with its muscles and the corresponding ligament and the semitendinosus muscle of the contralateral limb were freed. The distal ends of each ligament was marked with a suture and the freed muscle tendon units were photographed on the same plate. The ligaments were placed in 10 per cent neutral formalin. Paraffin blocks were made in the usual way. Longitudinal sections of the ligament and transverse sections of both ends and of the centre of the ligament were made. The specimens were stained with haematoxylin-eosin (van Gieson) and Masson's trichrome staining.

In all the series comprises 16 tendon reconstructions with pedicle grafts, 3 tendon transplantations with free grafts and 2 fascia lata transpositions according to Hey Groves (Tables 1-3).

Table 1 Results of transposition of pedicle grafts

No	Interval between reconstruction and taking of specimen weeks	Macroscopic finding	Histological finding	Remarks
1	4 $\frac{1}{2}$	Good	Living tendon	
2	4 $\frac{1}{2}$	Fair	Living tendon	Distal loosening
3	5	Good	Living tendon	
4	6	Good	Living tendon	
5	8	Poor	Infection	
6	9	Fair	Living tendon	Adhesions
7	9	Good	Living tendon	
8	10	Fair	Living tendon	Adhesions
9	10	Poor	Living tendon & degen tendon	Distal loosening
10	10	Poor	Living tendon	Adhesions, Infection
11	11	Good	Living tendon	
12	13	Good	Living tendon	
13	13	Good	Living tendon	
14	17	Good	Living tendon	
15	21	Good	Living tendon	
16	24	Good	Living tendon	

Table 2 Results of free tendon grafting

No	Interval between reconstruction and taking of specimen weeks	Macroscopic finding	Histological finding	Remarks
1	5	Good	Degeneration & necrosis	
2	6	Good	Degeneration & necrosis	
3	8	Good	Degeneration & necrosis	
4	9	Fair	Degeneration & necrosis	Adhesions
5	13	Good	Degeneration & necrosis	

Table 3 Results of Hej Crozes s reconstruction

No	Interval between reconstruction and taking of specimen week	Macroscopic finding	Histological finding	Remarks
1	5 $\frac{1}{2}$	Good	Degeneration & necrosis	
2	5 $\frac{1}{2}$	Fair	Degeneration & necrosis	

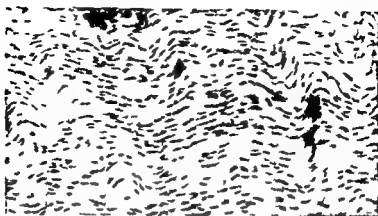


Figure 5 Normal tendon structure from a pedicle graft 9 weeks after transposition $\times 170$

RESULTS

Gross examination showed that the innervation of the semitendinosus muscle appears to be preserved after detachment of the muscle and transposition of the tendon.

The macroscopic intra articular findings varied. Sometimes the interior of the knee looked normal and sometimes there was a mass of adhesions and even infection. In Tables 1-3 the macroscopic findings, good indicates that adhesions if any were sparse and that the ligament appeared healthy, the knee more or less stable and the function of the limb satisfactory. Fair indicates some intra articular adhesions and that the ligament is somewhat loose. Poor indicates abundant adhesions, infection and a ligament loosened from its site of attachment.

Evaluation of the functional result was uncertain, some animals used their leg freely, others less well.

HISTOLOGICAL FINDINGS

A. Pedicle grafts. In all reconstructed ligaments the structure of the tendon was normal and the graft was vital (Figure 5). In some specimens near the distal insertion there was waxy degeneration and scantiness of nuclei centrally. The tendon was as a rule vital throughout with preserved vessels in which Microopaque suspension was often seen. Whether some of these vessels came from the distal insertion or only along the tendon could not be seen. In experiments on dogs, Peacock

ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

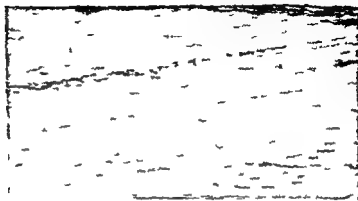


Figure 6 Loss of structure and homogenization of a free tendon graft 9 weeks after transplantation $\times 100$

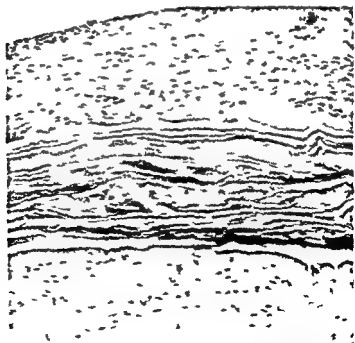


Figure 7 Necrosis of central portion of fascia transplant. Necrosis and disintegration in the periphery 5½ weeks after Hey Groves reconstruction $\times 100$

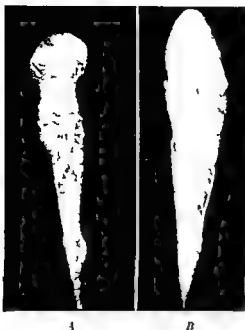


Figure 8 Example of angiograms of transposed muscle tendon unit (A) and of the corresponding structure of the intact limb (B) (Eleven weeks after the operation)

A

B

(1959) demonstrated that blood vessels entering long tendons from the muscular origin and periosteal insertion are able to nourish only the proximal and distal third of the tendon. The length of the tendon used in the present series is less than that of the digital flexors. From the histological specimens taken from transposed tendons it was as a rule impossible to conclude whether the graft had been in place for 4 or 24 weeks. When a longer period had elapsed since grafting the synovial membrane covered the ends of the graft and sometimes even the centre of it.

B Free grafts and fascia transplants. After transplantation with free grafts and fascia there was never a picture of a normal tendon or fascia but only of marked degeneration, disintegrating tissue and necrosis as well as inflammatory cell infiltration. Many cells were polymorphonuclear leukocytes, lymphocytes and undifferentiated cells. Neither fibroblast proliferation nor collagenization could be demonstrated with certainty. Occasionally necroses were seen and scar tissue which replaced the necrosis without showing any tendency to form ligamentary or tendon tissue (Figures 6-7). No vessels were seen in the transplants except capillaries at both insertions. Synovial membrane was seen on the surface of both ends of the transplants.

ANGIOGRAPHIC FINDINGS

Angiography was done in 13 cases. A filling was always obtained of the vessels of the muscle detached at its origin or tendon (Figure 8). In none of the muscle tendon units of the intact hind legs did the blood vessels in the area of the tendon fill with contrast medium while even in the distal end of three pedicle grafts and in two cases even along the tendon a thin pattern of vessels was seen which owing to the faintness of the picture cannot be reproduced here. These findings were verified in the histological specimens. In none of the cases of free grafting could vascularization be demonstrated at angiography neither could this be done in the Hey Groves transplant. Unfortunately microangiography proved unsuccessful.

DISCUSSION AND CONCLUSIONS

When an error in the technical performance or infection did not cause complications the result of transposition with pedicle grafts *i.e.* intra-articularly transposed grafts with preserved neurovascular elements was microscopically and histologically good. However free grafts and the fascial transplants comparable with them did not remain vital. The free grafts often seemed macroscopically healthy but histologically they appear to form fibrotic scar tissue only. When transferred into a joint the free grafts do not become adequately vascularized from their surroundings soon enough. For the assessment of the final fate of the graft the period of observation is short. As regards function the anterior cruciate ligament of the rabbit cannot be compared with that of man.

SUMMARY

A preliminary investigation on reconstruction of the anterior cruciate ligament of the rabbit is described. Only pedicle grafts with preserved vascularization and innervation remained vital while degeneration, necrosis and fibrosis occurred after transplantation with free grafts or distally based fascial strips.

RESUME

Une recherche préliminaire sur la reconstruction du ligament croisé antérieur chez le lapin est rapportée. Seules les greffes à pédicule préservant la vascularisation et l'innervation sont restées vitales alors que

la degeneration la necrose apparaissent apres transplantation de greffes libres ou de lambeaux de fascia de bises distales

ZUSAMMENFASSUNG

Eine vorläufige Untersuchung der Wiederherstellung des lig cruciatum anterius des Kniegelenks wird beschrieben. Nur gestielte Transplantate mit erhaltener Gefäßversorgung und Innervation erhielten sich lebensfähig während Degeneration und Nekrose von freien Transplantaten oder distal gestielten Fascienstreifen entstand.

REFERENCES

- Augustine H W Cited by Campbell's Operative Orthopaedics edited by J S Speed & R A Knight (1956) 3rd ed The C. V. Mosby Company St Louis
- Crozes F W Hey (1917-1920) Cited by Campbell's Operative Orthopaedics edited by A H Gresham (1963) 4th ed The C. V. Mosby Company St Louis
- Jones A C (1963) Reconstruction of the anterior cruciate ligament. A technique using the central one third of the patellar ligament. *J Bone Jt Surg* 45 A 925
- Hindemann K (1920) Über den plastischen Ersatz der Kreuzbänder durch gestielte Sehnenverpflanzung. *Z Orthop* 29 316
- Merle d'Aubigné R Cited by Fleat P (1962) Pathologie des ménisques et des ligaments du genou. Masson et Cie Paris
- O'Donoghue D H (1963) A method for replacement of the anterior cruciate ligament of the knee. *J Bone Jt Surg* 45 A 905
- Peacock F P (1959) A study of the circulation in normal tendons and healing grafts. *Ann Surg* 149 415
- Smillie I S (1969) Injuries of the knee joint 3rd ed L. & S. Livingstone Ltd Edinburgh

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FOLLOW UP EXAMINATION OF A SERIES OF ARTHRODESIS OF THE KNEE JOINT

By

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Received 16.6.67

When the working ability of a patient has substantially deteriorated owing to instability deformity or pain in the knee joint the possibilities of operation are few at the moment. In far advanced cases arthrodesis of the knee joint is often the only means of restoring the patient's ability to work.

Arthrodesis of the knee joint still has its problems. As the knee joint is situated between two long lever arms complete immobilisation during the consolidation period has proved difficult to achieve (*Morris et al* 1951 *Steward et al* 1958). This is the main reason why many methods of arthrodesis have not fulfilled the hopes placed in them and have been gradually abandoned (*Brittain* 1952). In 1948 Charnley drew attention to the advantages of the compression method (*Charnley* 1948). The method bearing his name was described by Key in 1932 and has gained an ever stronger position among operative methods for arthrodesis of the knee joint (*Key* 1932 *Charnley* 1948 1958 *Morris et al* 1951 and *Steward et al* 1958).

MATERIAL

At the Orthopaedic Hospital Invalid Foundation Helsinki during the period 1946-1967 arthrodesis of the knee was performed on 106 patients of whom 59 were men and 47 women. Age groups are shown in Table 1.

In no case was arthrodesis performed bilaterally. The youngest patient was 15 and the oldest 76. The longest observation period was 20 years and the shortest 1 year. 100 patients came to the follow up examination and follow up information is lacking in respect of 6 patients only.

Table 2 shows the grouping of the material according to the indication for operation.

Table 1

Age	Men	Women
Below 20	6	7
20-29	17	8
30-39	15	5
40-49	11	15
50-59	8	4
60-69	3	6
Over 70	—	2
Total	59	47

Table 2

Indication	Men	Women
Tuberculosis	29	18
Polio	8	8
Arthrosis	3	12
Fract	13	3
Rheuma	—	2
Other indication	6	4
Total	59	47

The largest group was tuberculosis though the proportion of this disease has steadily decreased in recent years. Among the aftereffects of polio arthrodosis was indicated by an unstable joint which hindered walking.

Pain after fracture was the result of secondary osteoarthritis. Seven such cases were the result of war wounds: five of accidents at work and one of a traffic accident. The other indication group includes the after effects of osteitis and of injury to soft tissues of the knee region where deformity or instability were indications for arthrodosis. There was one case of tabes dorsalis and one of other type of neurotrophic arthropathy.

METHODS

Four methods were mainly used in performing arthrodosis of the knee joint. Many different surgeons were concerned so that no far reaching conclusions can be drawn as to the superiority of one method over another.

By the Charnley method articular cartilage was removed in the normal way and opposing resected surfaces were pressed together with the Charnley compression device in fifty three cases. The limb was immobilised in a long plaster boot for six weeks after which the compression device was removed and the boot exchanged for

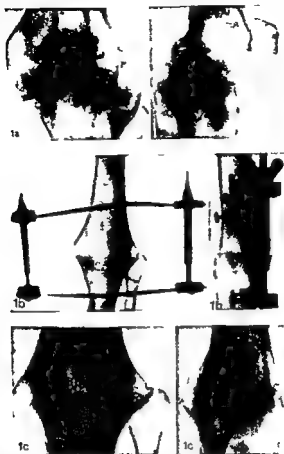


Figure 1 47 year old housewife dgn arthritis tuberculosa genus sin Patient's knee at angle of 150° after tuberculosis of knee Patient can only walk with crutches Mobility of knee 160-170° Patient also suffers from pulmonary tuberculosis A Condition before operation Anti tuberculous treatment started B Immediately after Charnley arthrodesis C Knee 6 months after Charnley arthrodesis Patient satisfied with result and walks without pain Patient again at work Anti tuberculous medical treatment continued for 2 years after operation

a plaster cylinder for 1-2 months. In 90 cases the patella was embedded over the arthrodesis area (Figure 1).

For screw fixation two spongiosa screws were used. These were screwed to the opposite condyle of tibia or femur in seventeen cases. The limb was immobilised either in hip spica or a plaster boot at a later stage of consolidation always the latter. Length of immobilisation was determined by the progress of consolidation which was checked at one month intervals both radiologically and clinically. It is especially in cases where the screws did not reach to the cortex in the

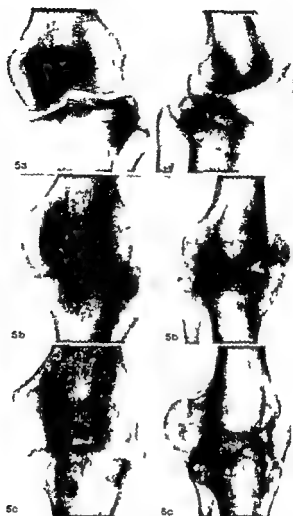


Figure 5 28 year old female furrier's assistant dgn Seq p p Parens extr inf 1 sin Patient had poliomyelitis at age of 13 left lower limb paralysed Left knee unstable tendency to dislocation Pain 4 Condition before operation B Arthrodesis performed without internal fixation but with patella embedded over resection point Condition shown here is 4 months after operation when arthrodesis was considered consolidated C Condition 18 years after operation Patient entirely without discomfort Patient does light work for a living

tion though the best results were clearly achieved by the Charnley method which usually produced consolidation in less than 3 months. A more exact definition of the consolidation period was not considered suitable in the present study because patients often came for post operative examination at intervals of 2-4 weeks. It is evident that in

some cases consolidation occurred in a noticeably shorter time than 11 months. The majority of complications and pseudarthroses appeared in cases without internal fixation. On the whole patients were satisfied with the results of operation and the only cases considered as failure were those in which infection made amputation necessary. Their number however was very small in relation to the total number of arthrodeses performed.

SUMMARY

The authors examined 106 patients on which arthrodesis of the knee had been carried out. One hundred patients arrived for follow up examination. Fifty nine were men and 47 women. The youngest patient was aged 15 and the oldest 76. The series includes 47 tuberculous knees, 31 with osteoarthritis from fracture or other cause, 16 with sequels of poliomyelitis. Four methods of operation were used as follows: Charnley's method—53; crosswise spongiosa screws—17; three wire coil compression—9 patients. In 27 cases there was no internal metal fixation. The fastest consolidation was obtained by Charnley's method, 36 cases ossifying in under 3 months and 46 in under 6 months. Results achieved by the various operative methods have been analysed and the aim of the follow up examination has been to elucidate the extent to which a stiffened knee has hindered a patient's working capacity.

RESUME

Les auteurs ont examiné les cas de 106 malades chez lesquels avait été pratiquée une arthrodeuse du genou et dont une centaine se présenterent à l'examen complémentaire. La série d'observations comprenait 59 hommes et 47 femmes. Le plus jeune malade était âgé de 15 ans, le plus vieux de 76 ans. Dans cette série de cas il y avait 47 genoux tuberculeux, 31 avec ostéoarthrite provenant d'une fracture ou d'une autre cause, 16 ayant des séquelles de poliomyélite. Quatre méthodes opératoires avaient été utilisées: méthode de Charnley 53, fixation spongieuse transversale par vis 17, compression par enroulement de trois fils 9. Dans 27 cas il n'y avait pas de fixation métallique interne. La plus forte consolidation avait été obtenue par la méthode de Charnley, 36 cas s'étant ossifiés en moins de trois mois et 46 en moins de six mois.

Les résultats obtenus par ces différentes méthodes opératoires ont

etc analysés et le but de l'examen complémentaire a été d'éclaircir dans quelle extension un genou raide a entravé la capacité de travail du malade

ZUSAMMENFASSUNG

Die Verfasser untersuchten 106 Patienten in denen eine Kniearthrodesis ausgeführt worden war. Einhundert Patienten kamen zur Nachuntersuchung. 59 waren Männer und 47 Frauen. Der jüngste Patient war 15 Jahre und der älteste 76. Reihenfolge umfasst 47 tuberkulöse Kniee, 31 mit Osteoarthritis nach Bruch oder anderen Ursachen, 16 mit Folgezuständen nach Poliomyelitis. Die vier folgenden Operationsmethoden wurden verwendet: Charney's Methode—53 gekreuzte Spongioschrauben, 17 Dreidrahtschlingenkompression, 9 Patienten. In 27 Fällen wurde keine innere Metallfixation gebraucht. Die rascheste Konsolidierung wurde mit der Methode von Charney erzielt, indem 36 Fälle unter 3 Monaten und 46 unter 6 Monaten verknöcherten.

Die mittels der verschiedenen Operationsmethoden erhaltenen Ergebnisse wurden analysiert und der Zweck der Nachuntersuchung war herauszufinden bis zu welchem Grade ein steifes Knie die Arbeitsfähigkeit des Patienten behindert hat.

REFERENCES

- Brittain H A (1952) Architectural principles in arthrodesis, ed. 2. E. & S. Livingstone Ltd. Edinburgh.
- Charney J (1948) Positive pressure in arthrodesis of the knee joint. *J Bone Jt Surg* 30 B 478.
- Charney J & Lowe H G (1958) A Study of the end results of compression arthrodesis of the knee. *J Bone Jt Surg* 40 B 633.
- Key J (1932) Positive pressure in arthrodesis for tuberculosis of the knee joint. *Sib med J* 25 909.
- Morris H M & Mosiman R S (1951) Arthrodesis of the knee. A comparison of the compression method with the non-compression method. *J Bone Jt Surg* 33 A 987.
- Steward Marcus J & Bland W Griffin (1958) Compression in arthrodesis. A comparative study of methods of fusion of the knee in ninety three cases. *J Bone Jt Surg* 40 A 585.

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OPERATIVE TREATMENT OF THE FOOT DEFORMITY IN CHARCOT MARIE-TOOTH DISEASE

By

STEN KARLHOLM & ULF NILSSON

Received 13.6.68

A particular type of progressive muscular atrophy was independently described in 1886 by both Charcot Marie and Tooth. It is characterized by symmetrical paresis particularly of the peroneal musculature for which reason the disease is frequently referred to as progressive peroneal muscle atrophy. There may also be paresis of the anterior tibial muscle, the extensor muscles of the foot and the gastrocnemius muscle. The posterior tibial muscle on the other hand generally displays a normal function. The impaired muscular balance results in a foot deformity consisting of an equino-varus-excavatus position. As the disease spreads symmetrical paresis may also arise in the muscles of the hand and the forearms. The paresis develops in a proximal direction but stops at the knee and elbow joints. This centripetal progression gives the affected limbs a form that is usually likened to an upturned champagne bottle. Advanced cases involve a considerable degree of invalidity—the patients can neither stand nor walk nor if the arms are affected can they perform manual work.

The etiology of the Charcot Marie Tooth disease is unknown. It is an hereditary complaint. Two main groups have been distinguished with a somewhat different prognosis according to the age at which the symptoms first appear (Allan 1939). In dominant heredity the symptoms appear around the age of 30, progress slowly and lead to a moderate impairment of the function of the muscles concerned. In recessive heredity the paresis appears before the age of 5, the muscular atrophy progresses rapidly and severe invalidity may have developed by the age of 15-20 years.

The literature to date has chiefly been concerned with the hereditary

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and neurological problems of the Charcot Marie Tooth disease. Less attention has been paid to the orthopedic aspects and there has been little discussion of the possibilities for surgical correction. Treatment of the foot deformity with a stabilizing subtalus arthrodesis in four cases has however been reported (Miller 1924).

In a large series presented more recently (Jacobs & Carr 1950) the surgical technique comprised lengthening of the Achilles tendon, plantar fasciotomy and triarticular subtalus arthrodesis according to Lamborn. In addition the anterior tibial tendon was transferred to the middle of the dorsum of the foot in some cases while in others the posterior tibial tendon was passed through a hole in the interosseous membrane and attached to the middle or lateral part of the dorsum of the foot. Out of 44 patients (i.e. 88 operated feet) 32 were reported to have excellent or 'good' results and the remainder poor results. However those described as 'good' included 6 cases with a recurrence of the varus deformity due to hyperactivity of the posterior tibial tendon which had been left in situ. The authors regarded the subtalus arthrodesis as the most important part of the correction but emphasized that the deformity tended to recur if tendon transfer was not performed as well.

OWN SURGICAL TECHNIQUE

In order to avoid bone surgery i.e. subtalus arthrodesis particularly in young patients the intention was to correct foot deformity by means of tendon surgery alone. The equinus position was dealt with by lengthening the Achilles tendon, the crevasus by plantar fasciotomy. The varus position was countered by transferring the powerful posterior tibial tendon. At the suggestion of one of us (S.H.) the previous technique was modified in that the posterior tibial tendon was transferred via a subcutaneous tunnel in front of the ankle joint and attached to the cuboid bone (Figure 1). When lengthening the Achilles tendon one must make sure that the tibial tendon can thereby reach its new insertion. After the operation the foot was kept in a plaster cast for 6 weeks in an overcorrected position i.e. dorsal extension and pronation.

CASES

This report concerns 4 patients (2 girls, 2 boys) all of whom have undergone a bilateral surgical correction of typical foot deformities in Charcot Marie Tooth's disease. 8 feet have thus been operating upon. The age at operation varied from 5½ years to 19 years, the symptoms having been present for about 3 years. Heredity was confirmed for 3 of the patients, the disease having afflicted both the mother, the maternal grandmother and a sibling of one of them. No heredity could be demonstrated in the fourth case.



Figure 1 Incisions for the operative technique

- 1 Lengthening of the Achilles tendon
- 2 Division of the insertion of the posterior tibial tendon
- 3 and 4 Subcutaneous tunnel anterior to the ankle joint for the posterior tibial tendon
- 5 Attachment of the posterior tibial tendon to the cuboid bone
- 6 Plantar fasciotomy

A preliminary report on these cases has already been published (Karlholm & Nilsson 1964). The average period of observation was short at that time but now ranges from 4½ years to 8½ years.

RESULTS

The primary results may be described as excellent in every case. Thus the transferred posterior tibial tendon functioned strongly enabling active pronation of the foot. Inspection showed normal weight bearing by the feet in standing though there was possibly a slight residual excavus position in one case. Walking capacity was also more normal and ordinary shoes could be used instead of supports or special shoes.

The primary improvement has been maintained throughout the period of observation in 3 cases (6 feet) (Figs 2 and 3). The stability of the feet is still good and the functional strength of the transferred posterior tibial tendon is unimpaired. In the fourth case—a girl who was operated upon at 1½ years of age—there has been recurrence and deterioration. The reason for this is a very marked progress of the muscular atrophy. The patient now suffers from severe invalidity with almost total paralysis of the feet and lower legs as well as marked paresis in the hands and forearms. The transferred posterior tibial tendon does not function actively though it does serve as a tenodesis.

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larly to cases with symmetrical changes especially if the peroneal muscles are found to be weak. We have not found any figures for the incidence of this disease in the literature. Having had our attention drawn to the condition however we have been able to diagnose an increasing number of definite cases. The complaint is perhaps not so uncommon as is stated in the usual textbooks. When confronted with a case of Charcot Marie Tooth disease one should call in the patient's closest relatives for an examination. Besides providing an opportunity to analyze the hereditary pattern which may be of prognostic value this enables one to assess and treat mild or undetected deformities of the foot.

Concerning the present surgical technique we wish to emphasize the particular importance of transferring the posterior tibial tendon. Placing this in front of the ankle joint gives a better leverage and hence an increased power of pronation compared with the technique of passing the tendon through the interosseous membrane. Moreover a subcutaneous tunnel undoubtedly provides freer passage for the tendon compared with a hole through the interosseous membrane which may lead to tenodesis. On the other hand transferring the posterior tibial tendon is not sufficient by itself. The equino-excurvatus position must also be corrected by lengthening the Achilles tendon and plantar fasciotomy.

The result of the operation was excellent in 3 cases (6 feet) and "poor" in 1 case (2 feet). It is thus possible for tendon surgery alone to correct and stabilize deformities of the foot in Charcot Marie-Tooth's disease. One can of course argue that equivalent results could have been achieved with a subtalar arthrodesis. In our opinion however and in view of the findings of Jacobs & Carr one must nevertheless transfer the strong posterior tibial tendon in order to avoid a recurrence of the deformity. We therefore conclude that bone surgery can be avoided and that tendon transfer can be sufficient.

Even in the case in which the result was classified as "poor" the tenodesis function produced a relative stabilization of the foot deformity. The muscular atrophy was obviously highly progressive in this case. The symptoms had appeared when the patient was only about 2 years old which suggests a poor prognosis and hence the indications for a tendon transfer were doubtful. The result of a subtalar arthrodesis would probably not have been any better. Moreover it has been shown that an early subtalar arthrodesis in congenital pes equinovarus does not produce the desired effect (Lempert 1965).

SUMMARY

The typical foot deformity in the Charcot Marie Tooth disease consists of an equino varus excavatus position. The deformity can be treated by soft tissue surgery alone. The operative technique is described. The prognosis depends not only upon the result of surgical corrections but also upon the inherent progressiveness of the muscular atrophies.

RESUME

La déformité typique du pied dans la maladie Charcot Marie consiste en une position equino varus-excavatus. Cette déformité peut être traitée par la chirurgie des tissus mous uniquement. La technique opératoire est décrite. Le pronostic ne dépend pas seulement du résultat des corrections chirurgicales mais aussi de la progression des atrophies musculaires qui s'y rattachent.

ZUSAMMENFASSUNG

Die typische Fussdeformität bei der Charcot Marie Tooth Krankheit besteht in einer equino varus excavatus Stellung. Die Verbildung kann mittels Weichteilchirurgie allein behandelt werden. Die Operations-technik wird beschrieben. Die Prognose ist nicht nur von dem Ergebnis der chirurgischen Korrektur sondern auch von der zugehörigen fortschreitenden Muskelatrophie abhängig.

REFERENCES

- Allan W. (1939) Relation of Hereditary Pattern to Clinical Severity as Illustrated by Peroneal Atrophy. *Arch intern Med* 63: 1123.
- Charcot J. M. & Marie P. (1886) Sur une forme particulière d'atrophie musculaire progressive souvent familiale débutant par les pieds et les jambes et atteignant plus tard les mains. *Rev Méd* 6: 97.
- Jacobs J. C. & Carr C. H. (1930) Progressive Muscular Atrophy of the Peroneal Type (Charcot Marie Tooth Disease). *J Bone Jt Surg* 32 A: 27.
- Karlholm S. & Nilsson U. (1964) Ortopediska och genetiska synpunkter på Charcot Marie-Tooths sjukdom. *Nord Med* 71: 163.
- Lempert R. (1963) Subastragalar Triarticular Arthrodesis for Congenital Club Foot in Children Aged 2½-15 years. *Acta orthop scand* 36: 203.
- Miller O. L. (1924) Reporting Cases of an Infrequent Type of Foot Deformity. *Southern Med & Surg* 86: 519.
- Tooth H. H. (1886) The Peroneal Type of Progressive Muscular Atrophy. London: H. K. Lewis.

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LEG MUSCLE STRENGTH IN BELOW KNEE AMPUTEES

By

LARS BACKLUND RUDOLF LENIPERG
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Received 29 1 67

In a series of unilateral below knee amputees using a prosthesis the isometric contraction power on flexion and extension of the hip joint on the amputated side and of the hip and knee joints of the other side was studied. The aim of the investigation was to study the extent to which amputation and the use of a prosthesis affected the muscle strength. This is of interest in the question of whether physical capacity and mobility of the distance which can be walked is limited by reduced muscle strength.

MATERIAL

Twenty patients eighteen men and two women were selected at random from a follow up series of unilateral below knee amputees (ten right sided and ten left sided) who had used a prosthesis for at least one year. The mean age was 59.4 years (range 15-58 years). The average time since the first amputation was 12.5 years (range 1-43 years). The reason for amputation was in most cases accidental injury. No patients had been amputated because of circulatory disturbances. None of the patients had clinical signs or a history of any other disease or injury that could limit his walking capacity.

The patients were informed beforehand that the investigations were of a purely scientific nature and that the results would not be used for disability assessment.

METHODS

The muscle strength in the lower extremities was measured by four different tests. These tests comprised measurement of the maximal isometric contraction power in the flexors and extensors of the hip joints and also in the flexors and extensors of the intact knee joint by methods described by Asmussen, Heebøll Nielsen & Molbech (1959), Bonde Petersen (1960) and Asmussen & Heebøll Nielsen (1961).

SUMMARY

The typical foot deformity in the Charcot Marie Tooth disease consists of an equino varus-excravatus position. The deformity can be treated by soft tissue surgery alone. The operative technique is described. The prognosis depends not only upon the result of surgical corrections but also upon the inherent progressiveness of the muscular atrophies.

RESUME

La déformité typique du pied dans la maladie Charcot Marie consiste en une position equino varus-excravatus. Cette déformité peut être traitée par la chirurgie des tissus mous uniquement. La technique opératoire est décrite. Le pronostic ne dépend pas seulement du résultat des corrections chirurgicales mais aussi de la progression des atrophies musculaires qui s'y rattachent.

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REFERENCES

- Allan W. (1939) Relation of Hereditary Pattern to Clinical Severity as Illustrated by Peroneal Atrophy. *Arch intern Med* 63: 1123.
- Charcot J. H. & Marie P. (1886) Sur une forme particulière d'atrophie musculaire progressive souvent familiale débutant par les pieds et les jambes et atteignant plus tard les mains. *Rev Méd* 6: 97.
- Jacobs J. E. & Carr C. R. (1950) Progressive Muscular Atrophy of the Peroneal Type (Charcot Marie Tooth Disease). *J Bone Jt Surg* 32 A: 27.
- Karlholm S. & Nilsson U. (1964) Ortopediska och genetiska synpunkter på Charcot Marie-Tooths sjukdom. *Nord Med* 71: 163.
- Lempert H. (1965) Subastragalar Triarticular Arthrodesis for Congenital Club Foot in Children Aged 2½-15 years. *Acta orthop scand* 36: 703.
- Miller D. L. (1974) Reporting Cases of an Infrequent Type of Foot Deformity. *Southern Med & Surg* 86: 512.
- Tooth H. H. (1886) The Peroneal Type of Progressive Muscular Atrophy. London: H. K. Lewis.

Figure 1 Measurement of strength of hip flexors Healthy subject



Figure 2 Measurement of strength of knee extensors left leg Healthy subject

Nielsen (1961)¹ For each patient the individual sex and the values for body height and age were taken into consideration. It can be seen in the table that the mean differences between the intact and amputated side for flexion and extension were 2 per cent and 6 per cent respectively although some individual patients exhibited larger differences. For the whole series however the mean value for hip flexion is distinctly lower than that reported by *Asmussen & Heeboll Nielsen*.

Table 1

	Hip flexion				Hip extension			
	Intact leg		Amp leg		Intact leg		Amp leg	
	kp	%	kp	%	kp	%	kp	%
N	40	77	44	70	48	104	45	98
n	20	20	20	20	20	20	20	20
Range	20-74	38-113	21-60	36-97	21-77	51-156	22-70	56-149
S.D.		17.2		17.2		20.1		20.1

Table 2a Able to Walk 1 Km

	Hip flexion				Hip extension			
	Intact leg		Amp leg		Intact leg		Amp leg	
	kp	%	kp	%	kp	%	kp	%
N	40	79	44	76	49	104	49	105
n	16	16	16	16	16	16	16	16
Range	20-74	39-113	21-60	36-92	21-72	51-156	21-70	71-149

Table 2b Unable to Walk 1 Km

	Hip flexion				Hip extension			
	Intact leg		Amp leg		Intact leg		Amp leg	
	kp	%	kp	%	kp	%	kp	%
N	43	77	40	72	43	90	33	73
n	4	4	4	4	4	4	4	4
Range	37-49	57-80	21-47	36-81	38-48	80-109	22-40	50-91

¹ The tables give the standard deviations found by *Asmussen & Heeboll Nielsen*. 5 patients out of the whole group showed values which were reduced by more than 2 S.D. with hip flexion on the intact and/or amputated side. Of these 1 patient was not able to walk more than 1 km. With hip extension one intact and one amputated leg (2 different patients) showed values reduced by more than 2 S.D.

Table 3 Muscular Strength in Knee Flexors and Knee Extensors Intact Leg

	Knee flexion				Knee extension			
	Right		Left		Right		Left	
	Torque Kpcm	%	Torque Kpcm	%	Torque Kpcm	%	Torque Kpcm	%
N	1 29	9%	1108	8%	1850	102	2000	110
n	10	10	10	10	10	10	10	10
Range	000 1050	6% 1%	0.0-1400	56-110	1100 2600	79 13%	1750 2700	64 162
SD		15		1%		18		18

Table 2 shows the percentage deviations from the normal values for the hip muscles when the series is divided into (a) a group of patients who stated that they could walk more than 1 km on flat ground and (b) a group of patients who stated they were unable to walk as far as 1 km. In group (b) lateral differences are seen with lower values for the amputation side.

Table 3 shows the mean percentage deviation from the normal values for the whole series on flexion and extension of the knee. Here also the patients were divided into two groups in the same way as above (Table 4).

Table 4a Able to Walk 1 Km

	Knee flexion		Knee extension	
	Right (%)	Left (%)	Right (%)	Left (%)
M	97	92	104	105
n	9	7	9	7
Range	87-121	62-107	79-135	64-129

Table 4b Unable to Walk 1 Km

	Knee flexion		Knee extension	
	Right (%)	Left (%)	Right (%)	Left (%)
M	104	89	85	120
n	1	3	1	3
Range	104	56-110	85	108-133

Seven of the 18 male patients were also tested with bicycle ergometry for measurement of the circulatory type of the physical work capacity (Sjostrand 1960). In 5 cases with values for muscular strength within the normal range normal circulatory conditions were found (mean value for $W_{130} = 700$ kpm/min). One of these patients could not walk more than 1 km.

In the other 2 cases a decreased physical work capacity was found ($W_{130} = 400$ resp. 450 kpm/min). One of them had a normal and the other a somewhat lowered muscular strength.

On knee flexion values reduced by more than 2 S.D. were recorded for 2 patients. The distance which one of the patients could walk was < 1 km. On knee extension no values were reduced below the limit of 2 S.D.

DISCUSSION

A large number of factors may affect the walking capacity in below knee amputees wearing a prosthesis. One parameter is the leg muscle strength both in the intact leg and on the amputation side. This investigation has shown that as a rule there is no marked reduction of the isometric contraction power either in the intact or the amputation leg. Although the values in some individual patients fall into the lowest part of the normal range reported by *Asmussen & Heeboll Nielsen* (1961) with the method used here the group as a whole shows normal values. The general reduction observed on hip flexion may, as mentioned above, possibly to some extent be related to the fact that in this test the possibilities of fixation for the patients were poor and therefore falsely low values may have been obtained. Normal subjects may also have fixation difficulties in this test, as has been found in another study on healthy males for whom in fact almost equally low values were noted (*Bäcklund & Nordgren* 1966).

Another explanation may be that the reduction in flexion power is a true one and due to the fact that the flexors in these patients are exercised less than the extensors. The training of the hip extensors is obviously adequate partly because of their function as antigravitational muscles and partly because of the special gait developed by persons using an artificial leg. On the other hand their inability to run or to walk quickly would be expected to result in inadequate training of the hip flexors.

The lateral differences recorded for hip flexion (Table 1) are not abnormal. In the normal series mentioned above differences of about 2 per cent were noted both for the hip and knee joint. Differences of the same order of size have also been reported previously (*Heeboll Nielsen* 1964). On hip extension the group as a whole showed a difference with 6 per cent lower values for the amputation side. This difference was on the average negligible (2 per cent) in the patients who were able to walk 1 km but considerable (22 per cent) in the other patients. This large lateral difference may however be due to chance in consideration of the fact that the number of patients who according to case history were unable to walk as far as 1 km was only 4 and that some individuals in both the other group and in the normal series showed lateral differences of the same order of size. The classification of the patients into those who were able and those who were unable to walk as far as 1 km may seem arbitrary. The borderline for a normal walk

ing capacity varies considerably *e.g.* with age but a maximal walking distance of less than 1 km is so low that it can be considered to indicate pathologically limiting factors.

Difficulties in fixation also seem to have played some role in the knee flexion and knee extension tests. Because of the test conditions the patient was placed in an eccentric position for left sided knee flexion and for right sided knee extension which probably affected the fixation of the trunk and thus may have given systematically lower values for these tests. No similar results were obtained for the normal series but this difference can probably be explained by the difficulty of the amputation patients in gaining a purchase with the artificial leg.

In spite of the shortcoming of the method which in some tests may have caused some systematic reduction of values in general no remarkable reduction of the leg muscle strength was shown in these unilateral below knee amputees. This finding contradicts the result of *Hettinger* (1959) who observed that in such patients there was a bilateral reduction of muscle strength in the hip both in the flexors and extensors. In addition he noted a lateral difference for the hip flexors with lower values on the amputation side. According to our overall assessment of the patients in this series in whom the strength reductions were accompanied by a limited walking capacity these reductions should be regarded as a *result of this limitation due to other factors rather than its cause*. Several of the patients with low values for muscular strength were able to walk further than 1 km and it follows therefore that decreased power in the muscle groups tested need not necessarily result in such pronounced limitation of the walking capacity.

One factor which is possibly of great importance for the walking capacity in these amputation patients is the occurrence of pain. Although pain of such extent as to limit the achievements of the patients did not occur in any of these tests all four patients who were unable to walk for more than 1 km complained of pain in the amputation stump on walking. On the other hand such pain only occurred in 2 of 16 patients who could walk for more than 1 km. It seems probable therefore that other factors especially pain on effort are of greater importance as regards the walking capacity of a patient with a below knee prosthesis than the muscular power of the legs. To judge from our findings physical training would have little influence on the walking capacity in such cases. However active exercises are of great clinical importance for other reasons by counteracting contractures and improving the patient's coordination and control of his prosthesis after leg amputation.

SUMMARY

The maximal isometric muscle strength for flexion and extension in both hips and in the normal knee was assessed in twenty unilateral below knee amputees wearing a prosthesis for more than one year. At hip flexion tests the bilateral values tended to be low. However the group as a whole showed values within normal limits.

In some individual patients a normal walking distance was found in spite of low muscle strength. Pain in the amputation stump on walking seemed to be of greater importance as a limiting factor.

RESUME

La force maximum isometrique du muscle pour flexion et extension dans les hanches et les genoux normaux a été établie dans 20 cas d'amputation unilatérale au dessous du genou chez des malades ayant porté une prothèse pendant plus d'un an. Au test de flexion de la hanche les valeurs bilatérales avaient tendance à être basses. Quoiqu'il en soit pour l'ensemble du groupe on trouva que les données constatées restaient dans le cadre des limites normales.

ZUSAMMENFASSUNG

Die maximale isometrische Muskelkraft bei Beugung und Streckung in beiden Hüften und im normalen Knie wurde bei zwanzig Personen mit einseitiger Amputation unterhalb des Knies, die eine Prothese länger als ein Jahr getragen hatten, geschätzt. Bei den Prüfungen der Hüftbeugung hatten die beiderseitigen Werte die Neigung niedrig zu sein. Die Gruppe als Ganzes zeigte Werte innerhalb normaler Grenzen.

ACKNOWLEDGEMENT

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REFERENCES

- Asmussen E., Heebøll Nielsen K. & Mølbech S. (1959) Methods for evaluation of muscle strength. Communications from the Testing and Observation Institute of the Danish National Association for Infantile Paralysis, Hellerup, Denmark. Nr 5 and nr III Suppl.
- Asmussen E. & Heebøll Nielsen K. (1961) Isometric muscle strength of adult men and women. Communications from the Testing and Observation Institute of

the Danish National Association for Infantile Paralysis Hellerup Denmark
Nr 11

- Bonde Petersen F (1960) Muscle training by static concentric and eccentric contractions *Acta physiol scand* 46 406-416
- Backlund L & Nordgren L (1966) En metodik for provning av isometrisk muskel styrka under standardiserade betingelser Foredrag vid Medicinska Riksstämman Stockholm
- Heeboll Nielsen K (1964) Muscular asymmetry in normal young men Communications from the Testing and Observation Institute of the Danish National Association for Infantile Paralysis Hellerup Denmark Nr 18
- Hettinger Th (1959) Die maximalen Drehmomente im Hüftgelenk bei Oberschenkel und Unterschenkel Amputierten im Vergleich zu Normalbeinigen *Zeitschrift für Orthopädie und ihre Grenzgebiete* 91 131-140
- Sjustrand T (1960) Functional capacity and exercise tolerance in patients with impaired cardiovascular function In H Gordon (Ed) Clinical cardiopulmonary physiology Ed II Grune & Stratton New York

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A CLINICAL TRIAL WITH INDOMETHACIN (INDOMEE®) IN LOW BACK PAIN AND SCIATICA

By

IAN GOLDIE

Received 20 II.67

INTRODUCTION

General Remarks on Inflammation and Antinflammatory Drugs

The antiphlogistic properties of certain drugs are often claimed to be combined with an analgesic effect (Gabril-a 1964 Sicuteri 1964 and Heilmann 1965). The background for this statement is the observed specific influence of the antiphlogistic agent on a particular sequence the assumed painproducing oedema in the process of inflammation. Some however have a centralanalgesic effect like e.g. phenylbutazone (Butazolidin®).

The inflammatory reaction is the response of mesenchymal tissues to irritation irrespective of its origin—mechanical thermal chemical or infectious. The sequence of events generally follows a well formed pattern in which however the time factor and other tissue reactions may cause alterations so that an irregular interchange of events may ensue rather than a linear development.

This unspecific tissue response contains a destructive and a reparative phase both of which are closely interconnected. The first includes haemorrhage formation of oedema local acidosis swelling and partial destruction of individual tissue components. Parallel to these reparative forces are instituted such as hyperemia exsudation of fibrin leucocytosis and phagocytosis. With these events in mind it may therefore be justified to use antiphlogistic agents with specific action on the destructive phase of inflammation which do not interfere with the reparative phase. Despite the assumed importance of oedema in repair

of injured tissues (*Asboe Hansen* 1963) it may be of some advantage to combat its formation as it is supposed that inflammatory swelling causes pain. Moreover *Rhoads et al* (1942) found that in retarded wound healing in hypoproteinemia oedema had a deleterious effect on the repair of tissues.

The action of antiphlogistic drugs thus becomes twofold the first being interaction in the destructive phase of inflammation and the second being analgesic in the diminishing effect on oedema.

Drugs used for antiinflammatory purposes have not been sufficiently selective in their action and their overall interference in cellular metabolism has had a deleterious effect on the proliferative phase. *Eg* the influence of corticosteroids on exsudation of fibrin and on fibroblastic activity which slows down the rate of healing (*Dougherty* 1954) is well known. *Sandberg & Steinhardt* (1964) have found that the retarding influence of steroids on wound healing depends on the inhibition of an enzyme histidinedecarboxylase. With the introduction of non steroid compounds such as phenylbutazone (*Butazolidin®*) oxyphenbutazone (*Tanderil®*) and indomethacin (*Indomec®*) it has been proved in experimental investigations that the proliferative phase is undisturbed (*Winter* 1964 *Brunius & Zederfeldt* 1965) and that the painproducing destructive phase with oedema is combated (*Winter* 1964).

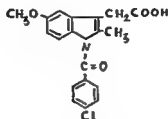
Problem

The origin of low back pain with sciatic irradiation is obscure and many explanations have been forwarded. The common and most accepted cause is the pressure a herniated intervertebral disc exerts on the nerve root. But mechanical factors are not the only painproducing agents and chemical degenerative and autoimmune reactions either primary or secondary to ruptures in the disc substance have to be considered (*Hirsch* 1965). They all form part of the inflammatory reaction and no doubt a nerve root can be interfered with by the sole products of an inflammatory development without the intervertebral disc material necessarily appearing as a herniation (*Hirsch* 1965 *Nachemson* 1965).

This study has therefore been carried out to assay the effect of—indomethacin (*Indomec®*)—in patients with an acute attack of sciatica.

Properties of Indomethacin (Indomee®)

Indomethacin is 1 (p chlorbenzoyl) 3 methoxy 2 methyl indole 3 acetic acid. It has formula of $C_{19}H_{15}NO_4Cl$ and a molecular weight of 357.8



It is relatively insoluble in water but is soluble in the common organic solvents (Shen *et al* 1963). Experimental studies (Winter 1964) show very active antiinflammatory properties. In inhibition tests on granulation tissue in rats indomethacin was 85 times more active than phenylbutazone and 4 times as active as hydrocortisone. Its inhibiting action on oedema has also been recorded in animal studies and it was 30 and 20 times as active as salicylates and phenylbutazone respectively but only twice as efficient as hydrocortisone (Winter *et al* 1963).

The analgesic effect has also been tested in clinical trials (Jacobs 1964) and 50 mg indomethacin has the same effect as 600 mg salicylic acid (Wanka Jones Wood & Dixon 1964 Percy Stephenson & Thomson 1964).

Side effects have been reported such as headache dizziness rashes and dyspepsia. In 1964 Lovgren and Allander reported several cases of peptic ulceration and haemorrhage two of which had a fatal outcome. Wanka *et al* (1964) have also reported on cases with gastric bleeding, and ulcers. Since the drug no longer has been administered as tablets but in capsules gastric side effects have almost completely disappeared. Besides these can be alleviated by taking the drug with meals.

Headache is as a rule transient (Hart & Boardman 1963) and dependent on the dosage. Hepatic renal and hematological complications have not been reported.

Indomethacin was originally introduced as an antirheumatic drug. As its antiphlogistic properties became more known the range of indications widened to include most conditions with pain secondary to tissue reactions of inflammatory type. Thus inflammatory reactions in periarthritic structures have appeared to be a good target for

treatment with indomethacin (Jacobs 1966) The dosage recommended is 75 mg-100 mg per day divided into three or four doses

METHOD

The trial was a blind inter patient comparison patients receiving a course of 50 capsules of either indomethacin or placebo The indomethacin was administered as capsules containing 25 mg of the drug a total of 75 mg being taken each day in three divided doses The placebo was administered in identical capsules three times daily

Neither doctor nurse or patient were aware of which treatment was given as the bottles in which the capsules were dispensed only had a number on the label the code of which was known only to the manufacturer

Only patients with true sciatica i.e. low back pain with irradiation down either leg were selected excepting six patients in whom the irradiation was not as constant but the back pain very severe The duration of symptoms did not exceed three weeks All but five patients were hospitalized and their reactions were read on day 1-5 and thereafter at weekly intervals up to at the most three months As indomethacin is said to institute its effect within 24-48 hours (Hurd 1964) it might have been sufficient with definite readings after this time but for the sake of completeness it was felt more appropriate to carry on the observations and make a conclusive registration after 14 days

As in many cases sciatica may be a self limited disease within this time the daily registration and final observation were however thought necessary to evaluate any possible radical influence the administered drug might have

No other drugs as sedatives hypnotics or supplementary analgesics were administered No physiotherapy was given The patients as a rule remained in bed for a few days and were allowed to move around freely

The following criteria were measured initially and on subsequent registrations All observations were made by the author

Subjective evaluation of pain The patient were asked daily about the intensity of pain and the relief was registered as complete fair or none using a score system with initial pain and no recovery recorded as 3 points lessened pain = fair relief = 2 points no pain = complete relief = 1 point.

Irradiation of pain The patients were asked daily if any change in irradiation was noted in either intensity or spread

Alteration in straight leg raising test The test was performed daily The difference before and after treatment was expressed in degrees and final registration was made after 14 days

Other neurologic signs

MATERIAL

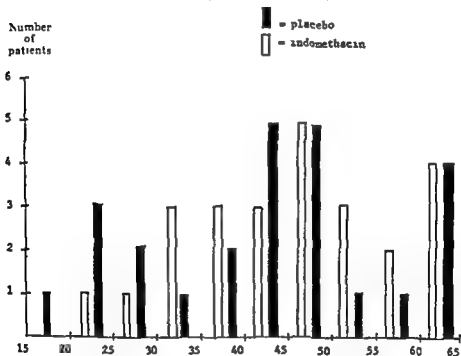
The total number of patients amounted to fifty

After decodification and division into indomethacin and placebo groups the distribution was as follows Table 1

The age distribution is seen in Table 2 and corresponds well with the distribution of lumbago and irradiating pain as reported elsewhere (Hirsch 1965)

Table 1 Distribution of patients in treatment groups after decodification

Sex	Indomethacin	Placebo
Male	13	13
Female	12	12

Table 2 Distribution of age and treatment of material

Duration of symptoms before treatment is seen in Table 3

Table 3 Duration of symptoms

Time	Indomethacin		Placebo		Total
	Male	Female	Male	Female	
One week	4	3	7	3	17
Two weeks	7	9	4	8	28
Three weeks	2	-	2	1	5

Side affected is seen in Table 4

Table 4 Localisation of pain

Sex	Lumbago ischias sin		Lumbago ischias dx		Lumbago ac	
	Indo methacin	Placebo	Indo methacin	Placebo	Indo methacin	Placebo
Male	4	8	6	4	3	1
Female	3	6	9	4	—	7
Total	7	14	15	8	3	8

Straight leg raising test before treatment is seen in Table 5

Table 5 Straight leg raising before treatment

Straight leg raising test	Indomethacin		Placebo		Total
	Male	Female	Male	Female	
Negative	7	7	6	9	29
Positive 10-40	3	1	1	1	6
Positive 40-80	3	4	6	2	15

RESULTS

It very soon became evident that decrease in pain was a slow process and that recordings would gain in reliability if measurements were made at slightly longer intervals. After seven days of treatment the subjective relief of pain was as follows, see Table 6

At the conclusive registration after 14 days the evaluation of pain was as seen in Table 7

Table 6 Subjective evaluation of pain after 7 days treatment

Relief of pain	Indomethacin			Placebo		
	Male	Female	Total	Male	Female	Total
Complete	5	2	7	5	4	9
Fair	4	4	8	4	5	9
None	4	6	10	4	3	7

Table 7 Subjective evaluation of pain after 14 days treatment

Relief of pain	Indomethacin		Total	Placebo		Total
	Male	Female		Male	Female	
Complete	9	5	14	7	9	16
Fair	—	1	1	2	—	2
None	4	8	10	4	3	7

Of the 17 patients with no relief 3 were later operated on for a herniated disc in the indomethacin group and 2 in the placebo group. These 5 patients still have complete relief of pain from 3 to 1 months after surgery.

The remaining 12 who had not experienced any relief of pain after 14 days were further checked for 3 months. Of these 10 had received physiotherapy and taken muscle relaxants and analgesics of various kinds. 5 had complete relief of pain, 3 still suffered constant but very mild pain which was alleviated by rest and light analgesics, 2 still suffered from such severe pain that admission for myelography was considered.

Straight Leg Raising Test

Indomethacin group After 14 days 4 were normalised, 7 remained as before treatment. Crossed straight leg raising pain was not observed.

Placebo group Of 10 positive 3 patients were normalised. In one patient crossed straight leg raising pain was present prior to the treatment. After 14 days therapy it remained. Those patients who were later operated for herniated disc from both groups had positive straight leg raising tests of 40–80.

Reflexes

Indomethacin group At initial examination no areflexia was registered in any case. At final registration after treatment no change was noted.

Placebo group At initial examination one patient responded with no reflexes at all. All the remaining had normal reflexes. At the conclusion of treatment the patient with areflexia still retained this. She did not belong to the group in which eventually operation was performed. No change in reflexes was observed in the remaining patients after treatment.

Sensitivity

Indomethacin group Normal sensitivity was encountered in all but two. These had reduced sensitivity for pain along the outside of the lower leg. After treatment the loss of sensitivity remained. They were later operated for herniated disc in the level L IV-L V. The sensitivity was not influenced by the treatment in the remaining patients of this group.

Placebo group Before treatment 5 patients had reduction of sensitivity. In 3 this corresponded to the radiation of the L V root and in 2 the S I root. Two of the former were operated for a herniated disc at the L IV-L V level. Normal sensitivity was encountered in the remaining patients in this group before and after treatment.

Big Toe Paresis

Indomethacin group Three patients had a big toe paresis before as well as after treatment. Of these two were operated for herniated disc at the L IV-L V level. The remaining patient had no paresis either before or after treatment.

Placebo group One patient initially had a paresis which remained after treatment. This patient was later operated for herniated disc at the L IV-L V level. No paresis was observed in the remainder of this group.

Table 3 Results of treatment on different signs

Signs	Indomethacin treatment		Placebo treatment	
	before	after	before	after
Straight leg raising				
Negative	14	11	15	18
Positive 10-40	4	1	2	1
Positive 40-80	7	6	8	6
Reflexes				
No absence	25	25	24	24
Absence	~	~	1	1
Sensitivity				
Normal	23	23	20	20
Reduced	11	2	5	5
Big toe paresis				
Not present	22	22	24	24
Present	3	3	1	1

Side Effects

In 13 patients headache nausea and giddiness were observed which in all instances appeared within some 24 hours after initiation of treatment To secure that the side-effects could be ascribed to the given preparation its administration was withdrawn for a few days and then reinstituted after disappearance of the side-effects They returned in all 13 patients within 12 hours after the second course of administration The side-effects were distributed as is seen in Table 8

Table 8 Side effects of administered preparations

Side effect	Indomethacin		Total	Placebo		Total
	Male	Female		Male	Female	
Headache	-	4	4	1	1	2
Nausea	-	4	4	-	2	2
Giddiness	-	-	-	-	1	1

COMMENT

Mechanical factors no doubt have a great importance in the pathogenesis of low back pain and sciatica As mentioned above however chemical degenerative and perhaps autoimmune processes are concomitant and may augment the role of mechanical factors in the mechanism which primarily elicits pain In 1958 Olsson came to the conclusion based on thorough animal experiments that large herniations of discs need not necessarily evoke symptoms but rather that a dynamic factor is responsible for the symptomatology and that this is an exponent for an inflammatory reaction For this reason he believed that the activity of the inflammatory reaction had to be combated as a therapeutic measure more than the removal of protruding disc tissue

In a study based on observations at operation for lumbago in humans Lindahl & Rexed (1959) showed that a pronounced fibrosis was present around the nerve root which supplied the segment from which the symptomatology originated Nachemson (1966) has investigated in a double blind trial the effect of oxyphenbutazone (Tanderil®) at operation for herniated discs with special reference to various factors such as hemoglobin leukocytes thrombocytes postoperative pain and haemorrhage during operation He found that oxyphenbutazone had a significantly reducing effect on haemorrhage

With the above observations in mind it therefore appears logical to

Sensitivity

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Normal	23	22	20	20
Reduced	2	2	5	1
Big toe paresis				
Not present	22	22	24	24
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handelt. Man fand keinen grosseren Unterschied in der Erleichterung der Schmerzen nach einer Behandlung von vierzehn Tagen. Vollständige Erleichterung der Schmerzen wurde bei 14 Patienten der Indomethazingruppe und bei 16 in der Placebogruppe gefunden. Kein Einfluss der Behandlung auf die Probe der Hebung des gestreckten Beines auf Reflexanomalien, Verlust der Sensibilität oder Parese des Extensor der Grosszehe konnte beobachtet werden.

In dieser Untersuchung war es daher nicht möglich irgendeine deutliche Wirkung der Indomethazinbehandlung in Fällen von Lumbago oder Ischias nachzuweisen.

REFERENCES

- 1 Asboe Hansen G (1963) *Annu Rev Physiol* 25 41-60
- 2 Ballabio C B (1965) *Internat Symp Non Steroidal Antiinflammatory Drugs Excerpta med* p 347
- 3 Beecher H K (1962) *Practitioner* 141 189
- 4 Brunius U & Zederfeldt, B (1965) Symposium über die posttraumatische Entzündung und ihre Behandlung S Karger Verlag Basel-New York, p 39-46
- 5 Cabitza A (1965) *Internat Symp Non Steroidal Antiinflammatory Drugs Excerpta med.*, p 434
- 6 Carlson A (1965) *Sc Lakartidn* 25/62 1977
- 7 Dougherty T & Scheibel C L (1955) *Ann N Y Acad Sci* 61 328-348
- 8 Hart E D & Boardman P L (1963) *Brit med J* 2 965
- 9 Hirsch C. (1965) *Sc Lakartidn* 45/62 3793
- 10 Hirsch C. (1966) *Applied Therapeutics* 8 857-867
- 11 Hirsch C. (1966) *Israel Journal of Medical Sciences* 2 362-370
- 12 Heilmann P & Olsson O (1962) *Sc Lakartidn* 59 2673 2682
- 13 Heilmann P (1964) *Nord Med* 71 363-365
- 14 Honigfeld H (1964) *Dis nerv Syst* 25 145 and 225
- 15 Hoyle & Evans (1965) *Cited Documenta Geigy*
- 16 Jacobs J H. (1965) *Proc Int. Symp Rec Advanc Non Steroid Antirheum Therapy Turin June 1965* p 73
- 17 Lindahl O & Rexed B (1950) *Acta orthop scand* 20 215-225
- 18 Lysell, E. (1964) *Sc Lakartidn* 61 3435
- 19 Lovgren O & Allander E. (1964) *Brit med J* 1 118
- 20 Miller J M., Gussberg M., Arce S Q., Bogosian A & Smith L B (1960) *AM & CT VII* 109
- 21 Nachemson A (1965) Symposium über die posttraumatische Entzündung und ihre Behandlung S Karger Verlag Basel-New York p 151
- 22 Nachemson A (1966) *Acta orthop scand* 37 267-275
- 23 Olsson S E. (1958) *J Neurosurg* 15 308-321
- 24 Percy J S., Stephenson P & Thompson M (1964) *Ann rheum Dis* 23 227
- 25 Rhoads J E., Fliegelman M T & Panzer L M (1962) *J amer med Ass* 118 21
- 26 Sandberg A & Steinhardt, C. (1964) *Acta chir scand* 127 574

- 27 Shen T Y (1963) *J amer chem Soc* 85 488
- 28 Selye H (1959) *Endokrinologie* 38 195 *Regensburger Jahrbuch Aertzt Fortbild* 7 1
- 29 Sicuteri F (1965) *Int Symp Non Steroid Antiinflammatory Drugs Excerpta med* p 335
- 30 Smyth C (1965) *Arthritis and Rheumatism VIII* 921
- 31 Wanka J Jones L I Wood P H N & Dixon A (1964) *Ann rheum Dis* 23 218
- 32 Winter C A Risby E A & Nuss G W (1963) *J Pharmacol exp Ther* 141 369
- 33 Winter C A Risby E A & Nuss G W (1964) *Fed Proc* 23 284

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CORTICAL BONE IN MAN

III Variation of Compressive Strength with Age and Sex

By

OLOF LINDAHL & ÅKE G H LINDGREN

Received 15 III 67

This is the third of a series of studies on cortical bone reports of which have been published in earlier issues of this journal (2 3)

MATERIAL

A full account of the material for this study has been given elsewhere (2). Compact cortical bone was taken from the femur and humerus of 64 autopsy subjects of various ages. As the femur is slightly curved the specimens for the compression test were taken from the posterior circumference of the bone which is usually subjected to compression while the tensile tests (3) were carried out on specimens from the anterior part generally subjected to traction. From the humerus the specimens were taken where the cortical bone was thickest and yielded most material.

METHODS

Storage

The specimens were stored in air at 3-5 °C (3). After preparation they were kept at constant temperature and relative humidity (20 °C and 65 per cent r.h.) until equilibrium with respect to the latter had been reached.

Test Bodies

The compressive tests were performed on test bodies 21-38 mm long removed in the axial direction of the bone by means of a facing cutter run at a low milling speed so as to avoid heating. The bodies were of rectangular and uniform cross section throughout their length with the dimensions 13-20 × 2.7-3.3 mm. These dimensions were measured with a micrometer and a variation of up to 0.01 mm was accepted within any particular test body. Two such bodies were made (or each bone (femur or humerus) with a few exceptions where because of the small dimensions and porosity only one could be obtained.

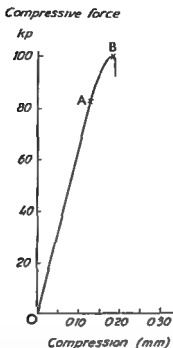


Figure 1 Force compression diagram for compression tests on a bone specimen. From O to A the curve is approximately straight and the compression proportional to the applied force. The stress (compressive force/cross sectional area of the body) for the bone at A is the limit of proportionality (kp/mm²). The compression at rupture (B) is expressed as the percentage deformation of the original length of the body. The modulus of elasticity is the ratio of stress to strain that is

$$\frac{\text{load/initial area of section}}{\text{deformation/original length}}$$

for the lineal part of the curve (O-A)

Apparatus

The test bodies were made and the compression tests carried out with an Alwetron apparatus at the National Testing Laboratory Stockholm. The rate of deformation was 0.05 mm/min. The deformation was recorded continuously and on the basis of the graphs so obtained the ultimate strength, compression at rupture, limit of proportionality and the modulus of elasticity were obtained (Figure 1).

Statistical Methods

The statistical analysis was performed with the same methods as in an earlier study (1).

RESULTS

The results are summarized in Table 1.

Table 1 Means of compressive strength parameters

The values in parenthesis are ranges

	Men		Women	
	Femur (n = 30)	Humerus (n = 30)	Femur (n = 30)	Humerus (n = 19)
Ultimate strength (kp/mm ²)	19.7 ± 0.3 (14.8-22.7)	18.8 ± 0.4 (13.3-21.4)	18.3 ± 0.4 (12.7-22.4)	19.1 ± 0.3 (16.4-21.7)
Compression at rupture (%)	5.3 ± 0.5 (3.5-14.8)	4.5 ± 0.3 (2.8-9.6)	4.3 ± 0.2 (2.8-7.1)	3.9 ± 0.2 (2.3-6.4)
Limit of proportionality (kp/mm ²)	15.8 ± 0.4 (10.1-18.3)	16.1 ± 0.4 (10.6-19.1)	15.7 ± 0.4 (9.3-20.5)	16.7 ± 0.3 (13.6-19.2)
Modulus of elasticity megap/mm ² †	1.05 ± 0.06 (0.30-1.76)	1.10 ± 0.05 (0.45-1.58)	1.07 ± 0.05 (0.46-1.55)	1.20 ± 0.07 (0.71-1.85)

1 kp/mm² = 14.70 lb/in² (psi)

1 megap = 1000 kp 1 kp (kgf) = 9.80665 newtons = 2.2046 lb force

1 megap/mm² = 14.70 000 lb/in² (psi)

Compressive Strength

There was no difference in the ultimate strength between the femur and humerus. The femur was significantly () stronger in men than women, with a mean difference of 8.0 per cent. There was a decrease in this property with age from 20 years upwards in both men and women and for both the femur and the humerus (Figure 2). The mean reduction was about 15 per cent and was significant ().

Compression at Rupture

For all age groups and both sexes the compression at rupture was greater for the femur than for the humerus; the difference was significant ().

For the men below 40 years there was a significant () reduction with age of about 40 per cent in the compression at rupture for both humerus and femur (Figure 3).

For women there was no such variation.

Limit of proportionality

This property showed no difference between the sexes or between the femur and the humerus. After 20 years there was a reduction of about 15 per cent with age (almost significant) (Figure 4).

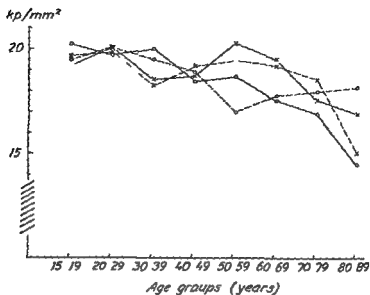


Figure 2 Mean compressive ultimate strength for the femur and humerus both sexes and various age groups Men \circ women \times femur — humerus ----

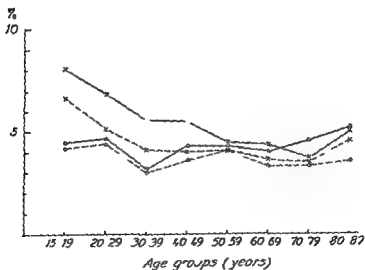


Figure 3 Mean compression at rupture for the femur and humerus both sexes and various age groups Men \circ women \times femur — humerus ----

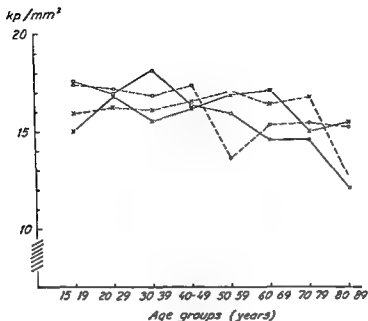


Figure 4. Mean limit of proportionality for the femur and humerus both sexes and various age groups : Men O women Δ femur — humerus ---

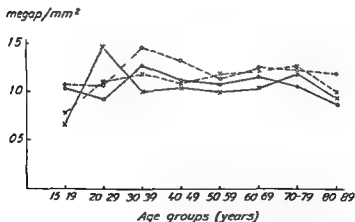


Figure 5. Mean modulus of elasticity for the femur and humerus both sexes and various age groups : Men O women Δ femur — humerus ---

Modulus of Elasticity

There was no difference between the sexes as regards the modulus of elasticity but in practically all the age groups and for each sex the value was higher for the humerus than for the femur the difference was almost significant () There was no variation with age (Figure 5)

DISCUSSION

As in the case of the tensile strength the measurement of the compressive strength indicated the presence of qualitative changes in the bone with age. The ultimate strength decreased by 15 per cent the compression at rupture by 40 per cent and the limit of proportionality by 15 per cent. Whereas the humerus had a higher ultimate strength at tension the femur showed a higher compression at rupture. This would seem to reflect functional adaptation the femur being subjected to compression more than the humerus.

In contrast to the values for the tensile strength for the compression there was a small difference between the sexes the ultimate compressive strength of the femur being significantly greater for men than women. It is difficult to judge whether this difference is due to a real difference between the sexes or to the composition of the material. The differences between the femur and humerus have another significance since the comparisons are made on the same subjects.

As in the case of the tensile strength the compressive strength showed extremely large individual variations. The means are in close agreement with those reported in the literature.

SUMMARY

A study has been made of compressive strength, compression at rupture, limit of proportionality and modulus of elasticity of cortical bone of the femur and humerus. The specimens were obtained from autopsy subjects of both sexes and a wide range of ages. There was a qualitative change in the cortical bone with age reflected in a reduction in all the properties except the modulus of elasticity.

RESUME

Il a été procédé à une étude sur la force de compression la compression à la rupture la limite de la proportionnalité et le module d'élasticité de

Los cortical du femur et de l'humerus Les specimens ont été prélevés à l'autopsie de sujets des deux sexes représentant une gamme d'âges variés. On a observé des modifications qualitatives de los cortical avec l'âge reflétant une réduction de toutes les propriétés excepté le module de l'élasticité.

ZUSAMMENFASSUNG

Ein Studie der Kompressionsstärke der Kompression bei der Sprengung der Grenze der Proportionalität und des Modulus der Elastizität von kortikalem Knochen des Femurs und Humerus wurde ausgeführt. Die Proben wurden von Autopsiesubjekten beiderlei Geschlechtes und weit verschiedenen Altersklassen erhalten. Man fand eine qualitative Veränderung des kortikalen Knochens entsprechend dem Alter, die sich in einer Verminderung aller Eigenschaften mit Ausnahme der Elastizität zeigte.

REFERENCES

1. Lindahl O (1961) Experimental skin pain induced by injection of water soluble substances in humans. *Acta physiol scand* 51 Suppl 179
2. Lindahl O & Lindgren A (1967) Cortical bone in man I Variation of the amount and density with age and sex. *Acta orthop scand* 38 135-140
3. Lindahl O & Lindgren A (1967) Cortical bone in man II Variation in tensile strength with age and sex. *Acta orthop scand* 38 141-147

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THE INTRODUCTION OF FORCE MEASUREMENTS GUIDING INSTRUMENTAL CORRECTION OF SCOLIOSIS

By

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Received 21 iii 67

A review of the extensive literature on the etiology of scoliosis reveals a singular lack of facts on which to develop sound hypotheses concerning treatment (Walgh 1966). Many authors have advanced theories, some of which have been partially substantiated by animal experimentation. These have been used to formulate new and presumably improved methods of treatment. That these procedures have not stood the test of time has been proved by the still newer methods that have replaced them. Such has been the rule, but a few exceptions do exist.

The Hibbs spinal fusion, the Risser turn buckle jacket, the Milwaukee Brace of Blount and Schmidt are well known, but very few others have found a place in the present-day treatment of scoliosis. However, the realization of the obvious inefficiency of correction techniques which depend upon transmitting pressure through the entire hemithorax to the vertebral column, or in applying traction to the skull and mandible, has driven many surgeons to adopt a more direct approach to the problem of correction. The excision of hemivertebrae for congenital scoliosis has been performed for the past 30 years, but it is only recently that opening and closing wedge osteotomies have been performed at the apex of idiopathic scoliosis curves to correct severe deformity. In 1955 Allan reported a series of scoliosis patients in whom he had inserted a metal jack on the concave side of the curve. Since that time several instrumentation techniques have evolved, culminating in the 1962 report by Harrington of his experience with the use of a compression and distraction device of his own design. Harrington has since stated that the correction by this technique was unmatched by any other system. There are, however, many surgeons who would question

the desirability of striving for a straight spine on the grounds that such attempts might endanger the vital contents of the trunk. The occurrence of the occasional catastrophe makes a cautious approach mandatory. However, within these limits, it is believed that progress can be made and new attempts should be encouraged to extend our knowledge and improve existing forms of treatment.

At the present time little is known about the etiology of idiopathic scoliosis, the most common variety of lateral deviation of the spine. Encouraging work is being done by *Ponseti* on possible mucopolysaccharide abnormalities in the disease and by *James* on the inheritance. But until such time as the pathogenesis is established and can be controlled, treatment must continue to depend on mechanical correction and maintenance.

Mild and moderate degrees of flexible spinal curvature can be treated successfully by plaster jacket correction and spinal arthrodesis. However, in severe degrees of deformity with minimal flexibility, such techniques may produce only 20 per cent to 30 per cent correction with the great likelihood that even this may be lost. It is in the severe cases that spinal instrumentation would appear most useful. The limiting factor, however, has frequently been the strength of the attachment, particularly to the thoracic area. Many surgeons performing spinal instrumentation have had the unpleasant experience of having their carefully placed hooks cut through the interarticularis. Such are the present problems with instrumentation that some authors, in reviewing their patients, have not found the results to be an improvement over those obtained with conventional forms of treatment.

With these problems in mind, it was thought to be essential to investigate the strength of conventional methods of attachment to the spine and explore other systems that might be less liable to failure.

A technique which used a mould of the posterior elements of self-curing methyl methacrylate was developed which proved to be two to three times stronger than any existing technique of attachment as tested statistically on autopsy specimens. However, toxic properties of this plastic exist due to the free monomer which is present in about 12 per cent concentration with autopolymerization. Although each attachment required only 0.1 ml of monomer, it was concluded that the implantation of acrylic in a child was not justifiable. It is believed, however, that the wealth of plastic materials which are being discovered will see the future development of a less toxic substance which would permit the safe use of such a technique.

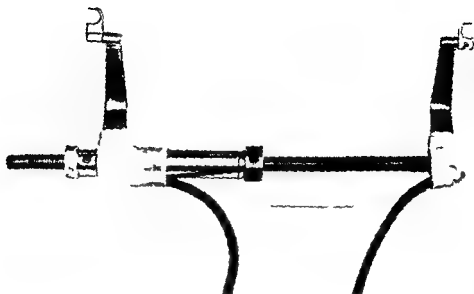


Figure 1 Distraction outrigger with gauges applied

As the limiting factor to the strength of any attachment is the area of contact a stainless steel hook was designed that closely approximated to the anatomy of the thoracic interarticularis and inferior facet. Although it had only 11 per cent greater surface area than the largest commercially available hook (Zimmer No 1253) the tested strength was 20 per cent greater. It was presumed that a reduction in stress concentration due to the contour caused the difference in levels of failure.

When testing of existing forms of attachment on autopsy material it was found that the commercially available Graca hook failed at $55 \text{ kp} \pm 10$. This failure occurred before the pedicle to which it would be attached in an anterior allopasty procedure. Because of the increase in angle or spread with the failure of these hooks it was believed that this could endanger the spinal cord. Such failure might be corrected by a stronger design. If it were desired to exert forces in excess of 45 kp failure would then be limited by the bony attachment and not the device itself.

The application to patients of information obtained from testing specimens extravitally, can only be made with considerable reservation. No accurate measurement has previously been carried out of the actual force necessary to correct a scoliotic spine nor is any informa-

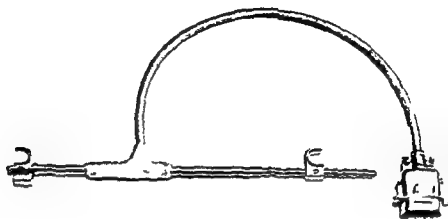


Figure 2 Zimmer No. 1200 Distraction Rod with strain gauges isolated by Silastic 352

tion available on the role of various elements in either causing, deforming or resisting correction. To accomplish such measurements electrical strain gauges were employed on an outrigger device and Zimmer No. 1200 rods to act as force transducers (Figures 1-4).

Three patients were selected for intravital measurements who required correction and fusion by the usual surgical criteria. The first two patients had moderately severe flexible curves; the third a resistant inflexible curve of severe degree. Measurements taken during spinal instrumentation procedure indicated that the flexible curves were readily corrected (60 per cent and 75 per cent) by forces of 20-30 kp, whereas the inflexible curve was corrected only 25 per cent by forces of this magnitude. A force of 38 kp was sufficient to cause failure of the thoracic attachment necessitating reposition of the hook at a higher level (Figures 5-8).

The posterior structures were released to determine which, if any of these resisted correction. In general there was little change recorded by releasing the paraspinal musculature, concave and convex, and the interspinous ligaments. Section of the apical intertransverse and costo-transverse ligaments produced a drop in force in one patient of 1 kp, but in another the results were inconclusive.

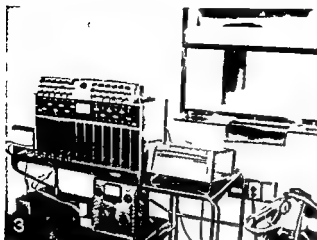


Figure 3 Electronic equipment for measuring strain (Peekel bridge type 112D4 and ABFM Ultralette 5550)



Figure 4 Calibration of distraction outrigger in materials testing machine

Complete paralysis by the injection of 50 ml of celocurin caused a 40 per cent fall in force when compared with that present during deep surgical anesthesia. Coincident with the return of spontaneous respiration the axial force returned to the original level.

Final correction was accomplished by insertion of the calibrated distraction rod to which isolated strain gauges were attached leads being brought out through the skin incision. With complete recovery from anesthesia there was no significant change in the recorded axial force on the rod. Coughing, and particularly vomiting were associated with brief momentary forces up to 68 kp. Voluntary sitting and standing on the day following surgery produced wide fluctuation in axial force but the highest figures obtained were only 20 kp.

On reexamining the spinal instrumentation procedure of Harrington on the basis of the information obtained from these extravital and intravital measurements the weak point of attachment of the distraction rod to the thoracic spine was confirmed. The compression system for the concave side of the curve was found to contribute insignificantly to reduction of the magnitude of the forces on the concave distraction rod. This would raise the question of the desirability of the additional surgery necessary to introduce the compression system.

Investigation of the deterioration curve of the axial force revealed a hyperbolic decline. For this reason distraction should be attained in slow increments giving the tissues time to adjust. When utilizing the



Figure 5 Frontal roentgenogram of Patient 1

Figure 6 Roentgenogram of distracted vertebrae in situ (Patient 1)

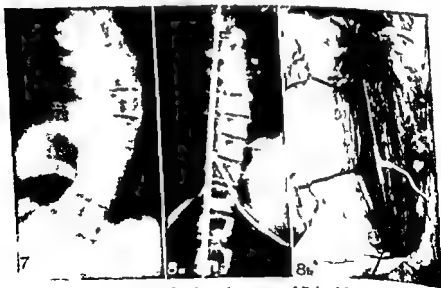


Figure 7 Frontal roentgenogram of Patient 2

Figure 8a & b Distracted vertebrae in situ prior to closure (Patient 2)

present commercially available methods of attachment for the Harrington technique the distraction force should not exceed 30 kp if a good margin of safety is anticipated

While it is not possible to use the measurements obtained to either advance or negate any of the existing theories of the etiology of idiopathic scoliosis one cannot but be impressed by several of the findings in this study. Contrary to expectation the force necessary to correct moderately severe scoliotic deformity was only in the order of 20-30 kp. This might suggest that the forces causing idiopathic scoliosis deformity are of equally small magnitude. The paraspinous musculature under anesthesia did not influence the deformity. However the intercostal muscles when paralyzed significantly changed the recorded axial force. This could raise the question of a possible etiological role of the intercostals in the development of idiopathic scoliosis. The interspinous ligaments did not appear to influence the deformity and the intertransverse and costotransverse ligaments did so in only one patient. On this basis their contribution to the scoliosis deformity is not determinable.

SUMMARY

1 The ultimate strength of lumbar and thoracic laminae has been estimated in autopsy material. Lateral parts are stronger than medial and lumbar spines tolerate more force than thoracic areas. The maximal tolerance was 40 kp in thoracic arches.

2 A device has been constructed recording the applied force during correction of scoliosis. It was used at surgery in two flexible and one resistant curvature.

3 Forces above 30 kp fractured the laminar bone of the patient. 30 kp was sufficient to correct 75 per cent of the flexible spines whereas the inflexible ones were only corrected 25 per cent by the same force.

4 It is suggested that correction should be done gradually perhaps at intervals of several weeks before the final fusion is made.

5 The inserted Harrington rods had wire connected built in strain gauges and the leads were brought out through the skin incision. Measurements were taken during the following 24 hours the patient being allowed to sit and stand. The highest figures obtained were less than 20 kp. The leads were then removed.

RESUME

1 On a procede sur un materiel d'autopsie a l'appréciation de la force ultime de l'arc postérieur des vertebres lombaires et thoraciques. Les parties laterales sont plus fortes que les parties medianes et la colonne lombaire supporte une plus grande force que la region thoracique. La tolerance maximum est de 40 kp pour les arcs thoraciques.

2 Un relevé a été établi enregistrant la force utilisée pour corriger la scoliose. Il a été utilisé en chirurgie dans deux courbures, flexibles et une résistante.

3 Des forces d'environ 30 kp entraînent la fracture de l'arc postérieur du malade. 30 kp suffisent pour corriger 75 pour cent d'une colonne flexible, alors que les colonnes inflexibles ont été corrigées avec seulement 25 pour cent de la même force.

4 Il est suggéré que la correction soit faite graduellement, peut être avec des intervalles de plusieurs semaines avant d'opérer la fusion finale.

5 Les tiges Harrington insérées sont reliées par fils à des jauges de tension introduites dont les fils sont ramenés à l'extérieur par une incision à travers l'épiderme. Des mensurations ont été effectuées durant les 24 heures suivantes, le malade étant autorisé à s'asseoir et à se lever. Les plus hauts chiffres obtenus ont été inférieurs à 20 kp. Les fils sont alors retirés.

ZUSAMMENFASSUNG

1 Die äusserste Stärke von lumbalen und thorakalen Laminae wurde an einem Autopsiematerial geschätzt. Die lateralen Anteile sind stärker als die medianen und Lendenwirbelsäulen ertragen eine grössere Gewalt als Brustwirbel. Die grösste Widerstandsfähigkeit war 40 kp im Gebiete der Brustwirbelsäule.

2 Eine Vorrichtung wurde konstruiert, die die angewendete Kraft während der Korrektur einer Skoliose angiebt. Sie wurde während der chirurgischen Behandlung von zwei beweglichen und einer steifen Kurvatur angewendet.

3 Kräfte von über 30 kp brachen den laminaren Knochen des Patienten. 30 kp waren ausreichend um 75 Prozent der beweglichen Wirbelsäulen zu korrigieren, während die unbeweglichen nur zu 25 Prozent mittels der gleichen Kraft korrigiert wurden.

4 Man schlägt vor, dass die Korrektur gradweise vorgenommen wer-

den sollte möglicherweise in Pausen von mehreren Wochen ehe die endgültige Versteifung ausgeführt wird

5 Die angebrachten Harrington Slabe hatten drahtverbundene eingebaute Belastungsmaßstäbe und die Leitungen wurden durch den Hautschnitt herausgebracht Messungen wurden während der folgenden 24 Stunden ausgeführt und der Patient durfte sitzen und stehen Die höchsten erhaltenen Zahlen waren unter 20 kp Die Leitungen wurden dann entfernt

REFERENCES

- Allan F G (1955) Operative Correction of Fixed Curves *J Bone Jt Surg* 37B 99
 Gruca A (1953) Operative Treatment of Idiopathic Scoliosis in Children Scot N Congress
 Harrington F R (1962) Treatment of Scoliosis Correction and Internal Fixation by Spine Instrumentation *J Bone Jt Surg* 44A 591
 James J I P (1965) Proceedings of a Symposium on Scoliosis Edited by P Zorab Action for the Crippled Child Monograph London
 Ponseti I V (1967) Pathogenesis and Etiology of Idiopathic Scoliosis *Acta Chir Orthop Traum Tech* 29 95
 Ponseti I V (1966) Personal Communication
 Waugh T R (1966) Intravital Measurements During Instrumental Correction of Idiopathic Scoliosis *Acta Orthop Suppl* 93

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TREATMENT FOR POTT'S PARAPLEGIA

By

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INTRODUCTION

Tuberculosis of the spine is today an uncommon disease in Western countries. In many other countries, however, it still has such a high incidence that it represents a constant and important challenge to the orthopaedic profession. The antituberculosis drugs have improved the prognosis, made possible more effective treatment, but have still not solved all the problems.

Literature on the treatment of tuberculosis of the spine is voluminous. Only a few authors, however, have dedicated their papers to paraplegia as their main subject. The present author feels that paraplegia constitutes such an important problem that it deserves special and separate interest.

For that reason it was felt that a review of cases of Pott's paraplegia treated in the Orthopaedic Department of the National Medical Center in Seoul, Korea, in the years 1959 to 1963 might be of some interest. The treatment represented two varying surgical methods—radical evacuation of tuberculous tissue with and without simultaneous anterior spinal fusion. This makes it possible to compare the results and evaluate the advantages of these two methods of treatment.

REVIEW OF LITERATURE

In this review only publications are surveyed in which the treatment of paraplegia is discussed.

Orthodox treatment (constitutional therapy with recumbency and mobilisation with or without additional antituberculosis drugs)

The results are not encouraging. A reasonable degree of recovery in 54 out of 67 with incomplete paraplegia was reported by Seddon (1935).

and complete recovery in 10 out of 23 *Aloul* (1949) Dobson reported on 136 cases in whom one in every four died and less than half made a worth while recovery (*Griffiths, Seddon & Roaf* 1956) Orthodox treatment with the addition of antituberculosis drugs in children was reported by *Kaplan* (1959) as 83 per cent recovery as compared to 58 per cent recovery without drugs

Antero Lateral Decompression

Griffiths, Seddon & Roaf (1956) reported in their above mentioned monograph on Pott's paraplegia the results of antero lateral decompression with 36 recoveries out of 50 paraplegic patients ✓

Radical Evacuation of Tuberculous Tissue ✓

Radical operation before the introduction of antituberculosis drugs was no success Some patients recovered but opening a tuberculous abscess had frequent and serious complications which presented a greater threat to the life of the patients than the paraplegia Following the introduction of the antituberculosis drugs *Wilkinson* (1949) *Hald* (1950) *Orell* (1951) *Kastert* (1951) *Kondo & Yamada* (1951) started to do a radical operation for tuberculosis of the spine Among their cases were cases with paraplegia *Bosworth* (1953) and *Fellander* (1954) respectively reported four improved out of five patients treated *Paus* (1964) reported the use of this method omitting enforcement of recumbency and immobilisation and had 10 complete recoveries in 21 patients

Radical Evacuation of Tuberculous Tissue with Anterior Spinal Fusion

Hodgson & Stocl (1956) approached the spine anteriorly. After removal of all tuberculous tissue including the surroundings as far back as the spinal cord they inserted strut grafts to keep the vertebral bodies sprung apart Among their first 100 cases they had 35 paraplegic patients with 26 complete recoveries Seventy five of their patients were children

PRESENT STUDY

Material

The material comprises 63 consecutive cases of Pott's paraplegia operated at the Orthopaedic Department of the National Medical Center

Seoul Korea during the years 1959-1963. In this period 315 patients with tuberculosis of the spine were treated at the department. The incidence of paraplegia in this series is 20.0 per cent. This incidence may be slightly higher than it would have been in a completely unselected group of patients as some paraplegic patients were given priority for admission to the ward.

The material was divided into two groups. Group I includes 33 patients operated by radical excavation of tuberculous tissue; group II includes 32 patients operated by simultaneous anterior spinal fusion. Two adults are included in both groups as they first underwent radical operation and later were reoperated by anterior spinal fusion because of unfavourable results.

Survey of Patients

Age distribution is given in Table 1. Children and adults in the two groups were nearly identical.

Sex distribution. There were 31 males and 32 females, evenly divided in group I and II.

Region of spine involved is given in Table 2. Only six cases involved the cervical or cervico dorsal spine, 50 the dorsal and 9 the dorso lumbar spine.

Number of vertebra affected averaged 3.2 in group I among the children and 3.4 among the adults, while it averaged 3.5 in group II among the children and 2.5 among the adults.

Sinus formation was rarely seen in combination with paraplegia.

Pulmonary and other tuberculous manifestations. Pulmonary tuberculosis occurred in eight of the 33 patients in group I and in 16 of the

Table 1 Age distribution

Age	Number of patients		Total
	Group I	Group II	
0-4	7	7	14
5-14	9	7	16
15-24	3	2	5
25-44	13	10	23
45-59	1	5	6
60 and above		1	1
	33	32	65

Two adults were included in both groups. (This goes for all tables.)

32 patients in group II Other complications occurred in three in group I and three in group II

Observation time is shown in Table 3

Summary The average distribution sex region of the spine involved number of vertebra affected and pulmonary and other tuberculous manifestations did not differ much in the two groups The average observation time is somewhat longer in group I than in group II

Table 2 Region of spine involved

Region	Group I	Group II	Total
Cervical	1	2	3
Cervico dorsal	2	1	3
Dorsal	26	24	50
Dorso lumbar	4	5	9
	33	32	65

Table 3 Observation time

Months	Group I	Group II
3-12	6	5
13-24	7	21
25-36	16	11
37-47	4	-

Survey of Paraplegia

Type (onset) of paraplegia Table 4 shows there were 54 cases of paraplegia where the paraplegia developed within two years after the first spinal symptom appeared and 11 cases were late paraplegia In children 27 were early and three late in adults 27 were early and eight late

Table 4 Type (early or late) of paraplegia

	Group I	Group II	Total
Early paraplegia	27	27	54
Late paraplegia	6	5	11
	33	32	65

Grade of paraplegia is shown in Table 5. In 50 cases the paraplegia was complete, in 15 cases it was incomplete. 29 in group I had spastic paraplegia, four had flaccid paraplegia. In group II all had spastic paraplegia, including one child who had quadriplegia.

Duration of spinal symptoms before operation is given in Table 6.

Duration of paraplegia before operation is shown in Table 7.

Table 5 *Grade of paraplegia*

	Group I	Group II	Total
Complete paraplegia	27	23	50
Incomplete paraplegia	6	9	15
	33	32	65

Table 6 *Duration of spinal symptoms before operation*

Years	Children	Adults	Total
Less than 2	23	22	45
2-10	8	12	20
	31	34	65

Table 7 *Duration of paraplegia*

Months	Group I	Group II	Total
1-6	15	12	27
7-12	8	8	16
13-24	8	7	15
25-48	1	4	5
49 and more	1	1	2
	33	32	65

The proportion of complete versus incomplete paraplegia in the early and late type of cases is shown in Table 8. The proportion of complete paraplegia was the same in children and adults, i.e. 21 children out of 29 and 29 adults out of 36. The proportion was the same also in early and late paraplegia, i.e. 42 in early cases out of 51 and eight late cases out of 11.

The proportion of complete versus incomplete paraplegia in relation to the duration of the spinal symptoms is shown in Table 9. Complete paraplegia was more common in cases with a spinal history shorter than two years 24 out of 45 than in cases with a longer history seven out of 20. The figures are too small however to draw any conclusion.

Finally the relationship between the grade of paraplegia and its duration before treatment is shown in Table 10.

Table 8 The proportion of complete versus incomplete paraplegia in early and late paraplegia

	Complete paraplegia		Incomplete paraplegia		Total
	Children	Adults	Children	Adults	
Early paraplegia	18	24	6	6	54
Late paraplegia	3	5	2	1	11
	21	29	8	7	60

Table 9 The proportion of complete versus incomplete paraplegia in relation to the spinal symptoms

Years	Complete paraplegia	Incomplete paraplegia	Total
Less than 2	24	21	45
2-10	7	13	20
	31	34	65

Table 10 Grade of paraplegia in relation to its duration before treatment

Months	Complete paraplegia	Incomplete paraplegia	Total
Less than 6	20	2	22
6-12	12	3	15
13-24	11	4	15
25 and above	2	6	8
	50	15	65

Treatment

Antituberculosis drug treatment before the patient came to our Out Patient Department. In group I only four patients had regular medica-

tion for some period of time and in group II one third had relatively regular medication before being seen by us. PAS and INH were given to the patients from their first visit to the Out Patient Department of the hospital. During their hospital stay streptomycin was given in addition. The period of medication (PAS INH) before operation varied between two weeks and 12 months depending on available beds in the ward and thus was left to chance. The medication period with SM varied between 10 days and two months. After discharge from the hospital medication with PAS and INH were continued for one year or more after operation.

Hospitalisation lasted from three to seven days before operation for additional examination and pre operative care. Hospitalisation following operation lasted eight days to two months. In group I it averaged 29 days and in group II 34 days. Of eight patients with more than 60 days five had pulmonary or urinary tuberculosis which needed further hospitalisation and three had complications of short duration.

No enforced recumbency or immobilisation was given in group I. In group II recumbency in a plaster bed was used for an average of three months in order to facilitate consolidation of the grafts thereafter replaced by a corset the application period of which varied between three and 12 months depending upon the extent of the lesions.

Operation Surgery in group I consisted of the evacuation of tuberculous tissue through an antero lateral incision in cervical cases and through a costo transversectomy in the other cases. Surgery in group II was done through an antero lateral incision in cervical cases and through a thoracotomy in dorsal cases and thoraco abdominal incision was used in lower dorsal and dorso lumbar cases. In group I 27 patients were operated on once while six had two operations and in group II 29 patients were operated once and three were operated twice.

OPERATIVE FINDINGS

Group I

In group I gross pathology was found in 31 cases inflammatory products were found in 31 cases sequestered material in 30. Small amounts of bone sands were found in three cases. Thirty three showed para vertebral soft tissue shadow on radiography an abscess was found in 19 granulation tissue in nine and caseous material in five cases. No abscess material was found in three cases.

In most cases it was not possible to inspect the cause of paraplegia

because of the limited approach but compression by sequestra was seen in two

By microbiological and histological examination acid fast bacilli and tuberculous granulation tissue were found in 20 cases tuberculous granulation tissue was found in 10 In three cases neither acid fast bacilli nor tuberculous granulation tissue were demonstrated

Group II

In group II the compressing agent was found in all cases The data are given in Table 11

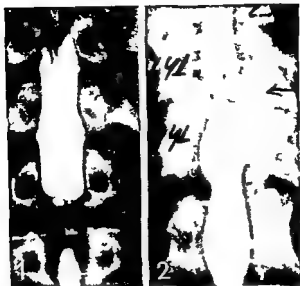
Operative findings in relation to the type (early or late) of paraplegia are given in Table 12

Table 11 The cause of the compression found in 32 cases operated by anterior spinal fusion

Inflammatory product	Abscess		4	}	9
	Granulation tissue		2		
	Abscess and granulation tissue		1		
	Caseous material		2		
Sequestered material	Bone	plus inflammatory	7	}	14
	Disc	product	4		
	Bone and disc		3		
	Sequestered bone and disc	plus fibr adhesion	2	}	2
Solid material	Bony ridge	plus intr	3	}	7
	Fibrosed mass of disc	fibrosis	1		
	Bony wall (vertebra)				
	Bony ridge and disc				

Table 12 Cause of compression and type of paraplegia

Inflammatory product
Inflammatory product and sequestered material
Solid material



Acid fast bacilli only were found in six cases acid fast bacilli and tuberculous granulation tissue in five and tuberculous granulation tissue in 21 cases

COMMENTS ON THE OPERATIVE FINDINGS IN GROUP II

a) *The Compression Agent*

Griffiths Seddon & Roaf (1956) commented on this particular problem and described this form caused by inflexion of the spine bony ridge in the floor of the spinal canal which is the commonest cause of late onset of paraplegia Hodgson (1960) reported on a similar case The present author observed seven cases of this particular cause of paraplegia

b) *The Relationship to the X Ray Findings*

Plain X ray and tomogram gave little information as to the cause of paraplegia even in cases where bony spurs were found to be the cause of compression at operation

Myelography on the other hand gave valuable information In one case a sharp indentation in another a complete block was demonstrated (Figure 1) In one case with concentric compression and strangulation of the dura myelography showed an "hour glass" formed

shadow (Figure 2) Three cases in the healing stage of paraplegia showed a complete block with small ears of contrast medium pointing to the periphery of the spinal canal Complete block seems to correspond to an extradural space filled up with fibrosis and adhesions

RESULTS OF OPERATION

The results of operation in group I and II are respectively given in Tables 13 and 14

As to the three children who had no recovery in group I all had extensive lesions and in one case the failure was proved to be due to collapse of the cord following operation which was observed at the second intervention In another the failure may be due to a similar cause The third died of pneumonia after three months

Table 13 Results of operation in Group I

Results	Children	Adults	Total
Complete recovery	13	10	23
Incomplete recovery	—	4	4
Failure	3	3	6
	16	17	33

One adult who recovered completely from completely paraplegia after radical operation however later developed recurrence of paraplegia is included

Table 14 Results of operation in Group II

Results	Children	Adults	Total
Complete recovery	14	14	28
Incomplete recovery	—	4	4
	14	18	32

COMPLICATIONS

In group I serious complications consisted of damage to the cord in two cases during surgery with subsequent complete paraplegia and the two earlier mentioned cases of excessive collapse during operation In one case a sinus formation in the wound healed after one month

In group II there were no serious complications. One thoracic duct was damaged when the intercostal arteries were divided close to the aorta. Immediate ligation was successful. In one case the lower end of the graft was found to be displaced two months after operation. Reoperation gave subsequent healing. Fracture of the graft was found in the post operative period in 11 cases where more than four vertebrae were affected and totally removed. They all healed subsequently.

There were no fatalities in either group in the immediate post-operative periods. In group I one child and one adult died from pneumonia three to 12 months after operation and a third died after six months cause unknown.

In group II there were no fatalities in the follow up period.

Factors Influencing the Results of Treatment

Age In this series the age of the patients seems to affect the results of treatment in the quality of the recovery and in the rapidity in regaining walking capacity after operation.

In group I complete recovery occurred in children in 13 out of 16 81.2 per cent in adults in 10 out of 17 58.7 per cent. Walking capacity within six months was established in 11 out of 16 in children 62.5 and in adults 6 out of 17 35.5 per cent. In group II complete recovery occurred in children in 14 out of 14 100 per cent and in adults in 14 out of 18 78.3 per cent. Walking capacity within six months was established in children in nine out of 14 64.2 per cent and in adults in nine out of 18 50.0 per cent.

The Duration of the Spinal Symptoms (until Operation)

In group I complete recovery occurred in 16 out of 21 76.2 per cent in patients with duration of the spinal symptoms of less than two years and in seven out of 12 58.3 per cent in patients with longer symptoms. Walking capacity showed no difference. In group II duration of the spinal symptom had no influence either upon the quality of recovery or upon the rapidity in regaining walking capacity.

The grade of paraplegia In group I complete recovery occurred in 18 out of 27 66.6 per cent in patients with complete paraplegia and in five out of six 83.3 per cent in incomplete paraplegia. In group II complete recovery occurred in 19 out of 23 82.6 per cent in patients with complete and in nine out of nine 100 per cent in incomplete paraplegia.

ing part of the vertebra and disc were removed in connection with an anterior spinal fusion. In this group an antero lateral cervical approach and a transthoracic or a thoracoabdominal approach were used.

The operative findings and the treatment results are compared and discussed. The transthoracic approach gave an excellent opportunity to inspect and to remove the compressing agent and seems to be preferable in cases of longstanding paraplegia where the compressing agent is often formed by solid masses.

This approach furthermore makes it possible at the same time to stabilise the spine by anterior fusion.

RESUME

Deux groupes pratiquement similaires de paraplegie de Pott en tout 65 cas sont rapportés. Dans le groupe I il a été pratiqué une extirpation radicale du tissu tuberculeux par incision cervicale antero latérale ou par costo transversectomie. Dans le groupe II le tissu tuberculeux et l'entourage de la vertèbre et du disque intervertébral ont été retirés en liaison avec une fusion spinale antérieure. Dans ce groupe on a eu recours à une approche antero latérale cervicale, une transthoracique ou une thoracoabdominale.

Les trouvailles opératoires et les résultats du traitement sont comparés et discutés. L'approche transthoracique a donné une excellente possibilité d'examiner et d'éliminer l'agent de la compression et semble être préférable dans les cas de paraplegie de longue durée où l'agent de compression est souvent forme de masses solidifiées.

Cette approche permet en outre de stabiliser simultanément la colonne vertébrale par fusion antérieure.

ZUSAMMENFASSUNG

Über zwei fast gleichartige Gruppen von Pott'scher Paraplegie insgesamt 65 Fälle wird berichtet. In der ersten Gruppe wurde eine radikale Entfernung von tuberkulosem Gewebe mittels einer antero lateralen cervicalen Inzision oder mittels Costo transversektomie ausgeführt. In der zweiten Gruppe wurden das tuberkulose Gewebe und der umgebende Teil des Wirbels und des Diskus im Zusammenhang mit einer vorderen Wirbelersteifung entfernt. In dieser Gruppe wurde ein antero lateraler cervicaler Zugang, ein transthorakaler oder ein thorako abdominaler Zugang verwendet.

Die operativen Befunde und Behandlungsergebnisse wurden verglichen und besprochen. Der transthorakale Zugang zeichnete Möglichkeit das komprimierende Agens zu entfernen und scheint bei Fällen von langdauernden Paraplegien das komprimierende Agens oft von soliden Massen vorzuziehen zu sein.

Dieser Zugang macht es ausserdem möglich die Verformung zeitig mittels vorderer Fusion zu stabilisieren.

ACKNOWLEDGEMENT

The author wishes to express his deep gratitude to two of the senior orthopaedic department the National Medical Center Seoul, Korea. Dr. Paus MD present chief of the Martine Hansens Hospital and Professor Arnt Jakobsen MD present chief of the Lægevakten gave me constant instruction and revised my work with untiring

REFERENCES

- Alvir J (1949) Tuberculosis of the spine—I An analysis and 507 patients *Acta chir scand* Suppl 141
- Bosworth D M, Pierta D A & Rahilly G (1953) Paraplegia resulting from tuberculosis of the spine *J Bone Jt Surg* 35 A 735
- Dobson J (1951) cited by Griffiths Seddon & Roaf (1956)
- Fellander M (1955) Radical operation in tuberculosis of the spine *Acta chir scand* 10 117
- Griffiths D L, Seddon H J & Roaf R. (1956) Pott's paraplegia
- Hald J (1954) Treatment of bone and joint tuberculosis with PAS *Acta tuberc scand* 30 82-104
- Hodgson A R. & Stock, F E. (1956) Anterior spinal fusion and its application on the radical treatment of Pott's disease and its complications *J Surg* 44 266-275
- Hodgson A R, Stock, F E, Fang H S & Ong G B (1959) The operative approach and pathological findings in the disease of the spine *Brit J Surg* 48 172-178
- Hodgson A R. & Stock F E (1960) Anterior spinal fusion in the treatment of tuberculosis of the spine The operative findings and the first one hundred cases *J Bone Jt Surg* 42 A 27
- Kondo E & Yamada K (1957) End results of focal debridement in the treatment of tuberculosis of the spine *J Bone Jt Surg* 39 B 1
- Kaplan C J (1959) Conservative therapy in skeletal tuberculosis based on experience in South Africa *Tubercle* 19 1
- Kästert J (1951) Kombinierte operative tuberkulostatische Spondylitis the Langenbecks *Arch Klin Chir* 270
- Kästert J (1957b) Die kombinierte operative tuberkulostatische Spondylitis tuberculosa *Ann Tuberc (Tent)* 8 14

- Orell E (1956) Surgical treatment of vertebral tuberculosis with the aid of chemotherapy and antibiotics *Reconstr Surg Traum* 3 46 S harger Basel New York.
- Paus H (1964) Treatment for tuberculosis of the spine antituberculosis drugs in conjunction with radical operation and short hospitalization with no enforced recumbency or immobilization *Acta orthop scand Suppl* 72 139 pages
- Seddon H J (1935) Pott's paraplegia: Prognosis and treatment *Brit J Surg* 22 769
- Seddon H J (1946) The pathology of Pott's paraplegia *Proc roy Soc Med* 39 769
- Wilkinson M C (1950) Curettage of tuberculous vertebral disease in the treatment of spinal caries *Proc roy Soc Med* 43 114-115
- Wilkinson M C (1952) The treatment of Pott's disease by curettage of the spinal lesion *J Bone Jt Surg* 34 B 153-154
- Wilkinson M C. (1955) The treatment of tuberculosis of the spine by excision of the paravertebral abscess and curettage of the vertebral bodies *J Bone Jt Surg* 37 B 382-391

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SURGICAL PROBLEMS IN HEMIPELVECTOMY

By

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By hemipelvectomy is meant an amputation in which the plane of resection runs in principle from the symphysis to the sacro-iliac joint half the pelvis and the extremity being amputated. Synonyms are hind quarter amputation and interpelvis abdominal amputation.

The first hemipelvectomy was performed in 1889 by Billroth but with a fatal outcome. The first successful operation by Girard came in 1890 (Pringle 1916). A total of 138 hemipelvectomies had been reported by 1946 (Wise 1949) though with a high operative mortality. Several large series have been published since for instance by Gordon Taylor & Monro (1952) and Pack & Miller (1964) and the operative mortality in these is considerably lower only 2 per cent in the latter. This progress is chiefly ascribable to improved anaesthesia and shock therapy. The indications for hemipelvectomy have been extended as knowledge of the biology and classification of the mesenchymal tumours has increased. Prosthetic improvements moreover have helped to reduce the functional invalidity resulting from the operation.

Experience has thus shown that this major surgery can be undertaken without undue risk. The purpose of the present paper is to discuss the surgical principles including the pre and postoperative assessments involved in hemipelvectomy. Our series of 13 cases is briefly reported at the same time.

INDICATIONS

The main indication for hemipelvectomy is the presence of a malignant mesenchymal tumour in the vicinity of the hip-joint with dissemination within the pelvic or the gluteal region. Among the bone tumours chondrosarcoma in the pelvis is the most common indication (Figures



Figure 1 Chondrosarcoma in the region of the ischial tuberosity

Figure 2 Chondrosarcoma emanating from the deep surface of the acetabulum and displaying pronounced intrapelvic expansion

1 and 2) fibrosarcoma being the most common among soft tissue tumours. If the tumour lies distal to the inguinal ligament but proximal in the thigh hemipelvectomy may be necessary in order to ensure a sufficiently radical resection. Moreover, since there is little functional difference between an exarticulation and a hemipelvectomy prosthesis the more radical measure can be recommended if it makes complete removal of the tumour more certain. Hemipelvectomy can also serve as a palliative measure if intrapelvic expansion caused by the tumour elicits compression symptoms from urinary tract, intestine or lumbar plexus. Pack & Viller also list skin tumours (melanoma) as an indication for hemipelvectomy. The use of this operation for pelvic osteomyelitis has been reported earlier but not in recent years, no doubt owing to improvements in antibiotic therapy. We have no personal experience of the last two indications.

PREOPERATIVE ASSESSMENT AND EXAMINATION

A correct diagnosis is obviously of fundamental importance for the surgical procedure. As for bone tumours in general this calls for close cooperation between pathologist, roentgenologist and orthopedic surgeon. We prefer surgical exploration, a biopsy always being performed so that the tissue samples for histopathological diagnosis are as representative as possible. The examination may be supplemented by needle biopsy for a cytological diagnosis.

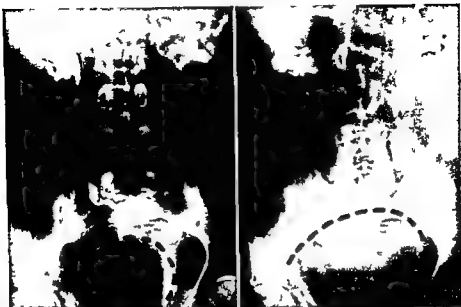


Figure 3 Urography in the same case as in Figure 2. The examinations were performed with an interval of 2 months, the patient having refused treatment after the first one. The righthand picture clearly shows dislocation of the contralateral ureter.

If the tumour has spread within the pelvis, urography and colon x-rays should always be undertaken in order to visualize the topography (Figure 3). One can then plan an extension of the operation in advance. If proliferation of the tumour makes it necessary to resect the ureter, a nephrectomy on the affected side must be done in conjunction with the hemipelvectomy. The urography will also provide preoperative information about renal function. If the colon is invaded by the tumour, a preoperative colostomy may be indicated.

An angiographic survey is often needed, particularly to locate the pelvic arteries. Here it may be noted that the femoral artery on the healthy side should be used for injection of the contrast medium. In several of the cases in which the angiography was performed via the diseased leg's femoral artery, subsequent vascular dissection was complicated by hematoma, oedema or perivascular fibrosis. This difficulty was specially marked in a case in which the external iliac artery had previously been catheterised for perfusion treatment with cytostatics. Angiography via the femoral artery on the healthy side also provides information about the circulation on both sides distal of the aortic

bifurcation. If it is then found for instance that the contralateral internal iliac artery displays pronounced arteriosclerotic changes allowance can be made for this at hemipelvectomy by avoiding ligation of the common iliac artery. Ligation of only the external branch leaves the ipsilateral internal iliac artery unimpaired thereby guarding against circulatory disturbances in the pelvic organs. It is possible however that this danger has been exaggerated. In a case of uterine rupture bilateral ligation of the internal iliac arteries did not give rise to any complications in the form of circulatory disturbances (Sjovall 1966).

The preparations for hemipelvectomy may also include the introduction of a ureteric catheter. If the tumour has expanded into the pelvic cavity it may be easier to locate the ureter by palpation of the catheter in the ureter wall. A bladder catheter is always introduced if the hemipelvectomy is expected to take a long time.

SURGICAL TECHNIQUE AND COMMENTS

The operation is performed with the patient supine, a small wedge shaped pad sometimes being placed under the lumbar region on the affected side. We consider this position advantageous because it permits rapid retroperitoneal dissection to the major pelvic vessels which can then be controlled. The lateral position reported by Sorondo & Ferre (1946) does not afford the same advantages.

The incisions are placed according to the tumour's extent particularly in the dorso proximal direction. A large anterior incision is generally made first running along the greater part of the iliac crest to the ventral iliac spine and from there along the inguinal ligament to the pubic tubercle and the symphysis. The abdominal musculature is freed from the iliac crest and the pubic tubercle, the peritoneum and the ureter are retracted medially and the vessels are followed in a proximal direction. The common iliac artery and vein are dissected free independently and fitted with rubber occlusion clamps as a precautionary measure. As pointed out by Wise (1948) and others one then has complete control in principle of major intrapelvic bleeding in the operation field.

Once it has been established that the tumour is operable the major vessels are ligated and cut. In most cases we have severed the external iliac artery and vein. In 3 cases the common vessels and in 1 case—owing to the anatomical relationships—the external and internal ves-

sels independently. A sufficiently radical excision of the tumour can generally be achieved with severance of only the external vessels. This also avoids the danger of circulatory disturbances arising in the region supplied by the internal iliac artery. This point has been heavily emphasised by *Ravitch* (1949) who holds that only the external artery can be severed with impunity. *Cordon Taylor & Monro* (1951) *Pack & Miller* (1964) and *Phelan & Nadler* (1964) always sever the common vessels apparently without adverse effects. In the cases in which we ligated the common (or internal) iliac artery no necrosis developed in the gluteal region. It would seem that the collateral circulation is sufficient to maintain viability. The femoral nerve and the psoas muscle are cut at the same level as the vessels.

The posterior and medial parts of the skin incision form the next step. The leg is adducted and rotated strongly inwards, the posterior incision being placed in a wide arc from the posterior superior iliac spine to the greater trochanter from where it turns down the gluteal fold towards the ischial tuberosity. From there it runs on the medial aspect along the pubic arch to the cranial border of the symphysis.

In the gluteal region we aim at retaining the gluteus maximus muscle so that after the amputation it can be sutured to the abdominal musculature and form a cover over the amputation field giving a stump of suitable consistence and strength. For this reason we sever the muscle at its attachment in the gluteal tuberosity and the fascia lata. In only 1 of our cases was the muscle resected, the defect being replaced with a tantalum net. Neither in this nor the other cases has hernia developed in the amputation stump.

The myotomies are followed by subperiosteal exposure of the region for the osteotomies at the symphysis and ilium. We generally make the anterior osteotomy through the pubic bone about 1 cm lateral of the symphysis in order not to risk injury to structures in the urogenital triangle. A Gigli saw is used for the osteotomy. The pubic angle is extremely acute in some men making it difficult to pass the saw round the bone. In such cases the anterior cleavage of the pelvic girdle had to be done through the symphyseal cartilage.

With respect to the posterior osteotomy prosthetic function and cosmetic considerations call for a resection plane that saves as much of the ilium as possible. The location of the tumour may however necessitate a very dorsal osteotomy in the sacro-iliac joint or even through the lateral part of the sacrum. If the osteotomy is made through the ilium the plane of resection coincides with the greater sciatic notch

bifurcation If it is then found for instance that the contralateral internal iliac artery displays pronounced arteriosclerotic changes allowance can be made for this at hemipelvectomy by avoiding ligation of the common iliac artery. Ligation of only the external branch leaves the ipsilateral internal iliac artery unimpaired thereby guarding against circulatory disturbances in the pelvic organs. It is possible however that this danger has been exaggerated. In a case of uterine rupture bilateral ligation of the internal iliac arteries did not give rise to any complications in the form of circulatory disturbances (Sjovall 1966).

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Figure 4 Frontal section of the condrosarcoma in Figure 2 The small incisure to the left is the acetabulum from the base of which the tumour measuring 11×11 cm is proliferating



Figure 5 Hemipelvectomy specimen (frontal section) of a synovial sarcoma The tumour has grown through the obturator foramen into the pelvic cavity

- 2 Performing the osteotomies in swift succession facilitates dissection of the tumour and control of bleeding
- 3 Encapsulated tumour with an extensive intrapelvic expansion accompany the pelvis after the osteotomies
- 4 The gluteus maximus muscle should be spared and used to build up an optimal stump. Resection of this muscle does not however necessarily result in insufficiency of the pelvic floor
- 5 Owing to the volume relationships a hemipelvectomy is considerably easier to perform on a child than on muscular or corpulent adults

POSTOPERATIVE TREATMENT

In our experience the patient is surprisingly unaffected by this major operation. Mobilisation is therefore possible on the 1st or 2nd postoperative day when the patient is stood up on the remaining limb. Walking exercises with a walking chair or supports are started as early as in the first postoperative week. As a rule the first prosthesis can be moulded about 3 weeks after the operation.

THE AUTHORS' SERIES

Our series comprises 13 hemipelvectomies. The age, sex and diagnosis for these patients are reported in Table 1.

Table 1 13 hemipelvectomies

Female	4	46-68 years
Male	9	11-69 years
<i>Fibrosarcoma</i>		3
<i>Synovial sarcoma</i>		2
<i>Angiosarcoma</i>		1
<i>Chondrosarcoma</i>		5
<i>Osteosarcoma</i>		2

There have been no immediate postoperative deaths. All the patients were discharged from the hospital with a prosthesis and varying degrees of walking function. The shortness of the present observation time—6 months to 4 years—precludes any assessment of the long term prognosis. It may be mentioned that *Pack & Miller* give the 5 year survival rate after hemipelvectomy for soft tissue tumours as 26.9 per cent and for bone tumours as 20 per cent. Our results to date are not

unfavourable (see Table 2) but more experience is required for an adequate assessment

Table 2 13 hemipelvectomies
Observation time 6 months-4 years

	I	II
Alive without metastases	4	II
Alive with metastases	1	1
Dead	1	4

I = soft tissue tumour

II = bone tumour

SUMMARY

The surgical considerations and technique in hemipelvectomy are discussed in detail with particular reference to methods for reducing operative complications. In the authors series presented here—13 cases with a maximal observation time of 4 years—there have been no deaths during or immediately after the operation.

RESUME

Il est discute en detail des considerations chirurgicales et techniques de l'hémipectomie en particulier par rapport aux methodes pour reduire les complications operatoires. Dans les series des auteurs presentes ici - 13 cas avec une periode maximum d'observation de 4 ans - il n'y a pas eu de deces pendant ou immediatement apres l'operation.

ZUSAMMENFASSUNG

Die chirurgischen Überlegungen und die Technik bei der Hemipectomie werden eingehend und mit besonderer Bezugnahme zu Methoden die operative Komplikationen herabsetzen besprochen. In der von den Verfassern hier vorgestellten Gruppe - 13 Fälle mit einer maximalen Beobachtungszeit von 4 Jahren - ereignete sich kein Todesfall während oder unmittelbar nach der Operation.

REFERENCES

- Gordon Taylor C & Monroe R (1931-1932) The technique and management of the hindquarter amputation *Brit J Surg* 39 536
 Pack, G & Miller Th. (1964) Exarticulation of the innominate bone and corresponding extremity (Hemipelvectomy) for primary and metastatic cancer *J Bone Jt Surg* 46 A 91

- Phelan J T & Nadler H H (1964) A technique of hemipelvectomy *Surg Gynec Obstet* 119 311
- Pringle J H (1916-1917) The interpelvic abdominal amputation *Brit J Surg* 4, 283
- Ravitch M M (1949) Hemipelvectomy *Surgery* 26 199
- Sjovall A (1966) Bilateral ligatur av A hypogastrica *Nord Med* 75 601
- Sorondo J P & Ferré R L (1946) Interinnomino abdominal amputation Interamerican Congress of Surgery Montevideo
- Wise R. (1948) Control of the common iliac artery during sacroiliac disarticulation (Hemipelvectomy) *Ann Surg* 128 993
- Wise H (1949) Hemipelvectomy for malignant tumours of the bony pelvis and upper part of the thigh *Arch Surg* 58 867

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CAPITAL FEMORAL EPIPHYSIOLYSIS TREATED BY PLUGGING WITH CORTICAL BEEF BONE

By

STEWART M SCHAM

Received 8 II 67

Treatment of capital Femoral epiphysiolysis by plugging or epiphysiodesis is well established though not widespread and has been used in several hundred cases. In the reported cases autogenous cancellous bone of local and iliac origin has been used. At Sophies Minde cortical beef bone processed in the hospital is used. The purpose of this report is to evaluate this technique and also to emphasize again a valuable early radiological sign in epiphysiolysis which has previously been described.

Two results are sought from the plugging operation: the prevention of further slip and accelerated closure of the cartilaginous growth plate. An advantage is that no second operation is required to remove metallic fixation material such as a Smith Petersen nail or threaded pins. Possible disadvantages are that in the plugging operation which is intracapsular infection if it occurs will be very serious and that the incidence of ischemic necrosis of the femoral head might be increased.

DIAGNOSIS

The usual diagnostic signs and symptoms sought upon hip or knee complaints in an adolescent are well known. A less well known early radiological sign has been described by Capener (1956), Durbin (1960) and Jacobs (1962). This is the extrusion of the diaphyseal component of the caput femorale from the acetabular contour and is seen on the frontal film. This means that the dense triangle normally seen below the caput's main epiphysal portion and resulting from overlapping of the lower part of the acetabulum with the diaphysis of the neck, is not present. Of course the usual other radiological findings are found, particularly those on the lateral view. But this sign is occasionally the only finding in an early case as in

4 of 24 hips *Jacobs* reviewed. It was the only sign in 1 and possibly 2 of the hips in this paper. As *Jacobs* points out, it is of special value when the clinical diagnosis is unsuspected so that a lateral film is not taken. For example, in the usual follow-up of a patient with known unilateral disease without complaints on the opposite side, lateral films on that side may not perhaps be made. In these cases it is a particular advantage to be able to utilize a sign visible early on a routine film and offering a very high degree of reliability.

In case 5959 of this report it is seen in the clinically normal right hip which went on to undiagnosed slip and progression. See Figure 7a-c. The final appearance in the hips of this case is that frequently seen in hips which some surgeons feel are particularly susceptible to osteoarthritis. This suggests that undiagnosed epiphyseolysis may be a more common cause of Primary osteoarthritis than is generally realized.

MATERIAL

Thirty-six patients whose clinical records and x-ray folders were studied are reported. For the purposes of this report, final clinical examination of the patients by the author was not necessary. Nineteen were boys and seventeen were girls, giving the anticipated slight male preponderance. Four boys and four girls had bilateral disease; an incidence of bilaterality of 22 per cent. Because thirteen uninvolved epiphyseal plates were open at the last follow-up, a slightly higher bilaterality rate could occur. Thirty-two cases had slipped less than 30 per cent, 7 between 30 and 50 per cent and 4 over 50 per cent. One case could not be evaluated for degree of slip. Two of the minor slips were discovered only on reviewing the x-rays and being clinically unrecognized, were untreated.

The average age at operation was 13 years, 1½ month. The oldest was a boy 16 years and 7 months old and the youngest a girl 9 years and 10 months old without a history of trauma. The average boy at operation was 13 years 11 months old, the average girl 12 years and 2 months. This coincides with the usual age difference of 2 years between boys and girls, presumably related to difference in bone age.

TREATMENT (See Table 1)

The two S-P nailings were performed elsewhere before admission to Sophie's Clinic. Of the 10 osteotomies, 3 were intertrochanteric, one was subcapital and one was through the lower third of the neck. They were all fixed with staples except for the subcapital one which was held with the bone plugs. Five of the intertrochanteric osteotomies had bone plugs introduced through the osteotomy site.

Table 1 Treatment of 55 hips

Total number with plugging alone	29
Total number with osteotomy alone	2
Total number osteotomy plus plugging	8
Total number with S-P nail	2
Total number untreated	3
Total number of hips involved	44

On admission the cases were placed in slightly abducted otherwise straight bilateral skin traction of 2-3 kilograms. A few had tibial skeletal traction. Surgery was not done as an emergency. The incision approach was between the tensor fasciae lata and gluteus medius. The capsule is longitudinally incised and the neck and site of slip seen. Drill holes of about 1/4 inch are made into the head through the neck starting antero laterally. Cortical beef bone plugs are then shaped to fit and driven in according to length determined by placing a thin K wire into the drill hole and rotating the femur to see when the wire no longer moves with the femoral neck. The capsule is loosely closed. Traction continues for 10 weeks after surgery. Active and passive exercise begins one to two weeks after surgery. Traction is discontinued at 10 weeks but bed rest continues 6 weeks longer. Then gradual weight bearing with crutches begins.

Röntgen films are made at 10 and 16 weeks and thereafter at intervals of several months.

RESULTS

1 Obliteration of the Growth Plate

Seventeen male hips were evaluated in this respect and twelve female hips both groups being treated with plugging. Fourteen normal hips five male and nine female were also evaluated. The results are in Table 2. These times seem rather long. It should be stated that what is referred to here is complete disappearance of the cartilaginous growth plate including the small portion laterally which was generally seen to disappear last. Bone trabeculae crossed the plate in every case earlier usually by several months. However it is difficult to evaluate when bone trabeculae first cross a plate or when there are enough crossing to assure stability. Therefore the endpoint of 100 per cent closure was chosen. If the plate were almost closed at one date and completely closed on the next study several months later the latter time was chosen. See Figures 1, 2, 3 and 4a, b, c to see when closure is accepted in comparison to when closure for clinical purposes is apparent.

Table 2 Obliteration of growth plate time after plugging and age in normal and plugged hips

	Male	Female
Average age following plugging operation	15 years 9 months	13 years 4 months
Average time following plugging operation	129 months	14 months
Average age in normal hips	16 years 7 months	13 years 11 months



Figure 1 Closure is not roentgenologically complete but clinically adequate

Figure 2 a) both not considered completely closed b) was taken 9 months after operation



Figure 3 Almost 11 years after surgery clearly clinically closed but not 100 per cent roentgenologically



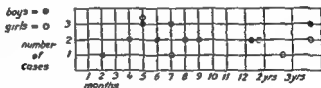
Figure 4 a b c a) Is clinically closed as is b Full roentgenological closure was accepted with c 15 months after surgery

FEMORAL EPIPHYSIOLYSIS TREATED BY PLUGGING

Howarth reporting on results with autogenous iliac plugs in 1963 reported obliteration of the epiphyseal plate within a year Heyman Herndon in 1954 reported that cancellous bone plugs produced roentgenographic evidence of fusion within three months after operation. In the present series though average obliteration took a little over a year these were average values. Several cases took well over one year suggesting that beef cortical plugs are not as efficient in this regard as the autogenous cancellous plugs. See Table 3.

No cases in this series slipped after plugging so that clinically adequate healing actually occurred within four months when ambulation began.

Table 3 Breakdown of closure times
Three boys and 3 girls required over 2 years for full plate obliteration



2 Evaluation of Matters of Technique Bone Plugs

70 plugs were used. As evaluated on routine 2 view study and regarding the concavity of the growth plate 13 or 16 per cent of plugs did not cross the plate. In three of the 37 cases plugged or 8 per cent no plugs crossed. None of these cases slipped further.

In 6 cases a plug protruded through the head into the joint space and in one the plug clearly entered the acetabular cartilage. No harm was noted except in the latter case to be discussed later. Bone in joint space either backed into the head or broke off the loose fragment usually becoming invisible within one year.

In many cases plugs at the site of entry into the neck were allowed to protrude to a varying degree above the neck surface. This protrusion either resorbed or rounded out and only one case to be discussed became a problem.

In distinction to autogenous cancellous bone beef cortical plugs were visible clearly on x ray study for a long period. Initial host invasion as determined by distinct rather uniform serrations on their edges was seen an average of 4 months after operation. The time required for complete plug disappearance varied greatly a few becoming invisible in 1 year and some clearly visible after six to eight years.

Figure 5 a b Shows plug fragments unchanged in 7 years



Figures 5a and b show bone plugs protruding on the neck unchanged 7 years after surgery

Osteotomies

Of the 7 intertrochanteric osteotomies and one just above the greater trochanter all fixed with staples which were treated similarly to plugged cases afterwards all healed in 3 to 4 months Five of these had plugs through the osteotomy site which in no apparent way interfered with healing

A sub capital osteotomy held with the bone plugs through the neck fell apart It was then reduced and fixed with an S P nail Interestingly this case a 50 per cent ship at the start did not develop necrosis with a follow up of 3 years and 1 month The 10th osteotomy was through the lower third of the neck held with 2 staples It dislocated and required re operation with new fixation applied on the neck Necrosis and deformity followed

Antibiotics and Infection

No infections occurred

Over one half of the cases received Penicillin from the day of surgery to a variable post operative period See Table 4 There is no significant difference in the post operative temperature curve for the two groups

Table 4 Comparison of average temperature curves 10 days post op in cases with plugging only with and without antibiotics

Post on day	1	2	3	4	5	6	7	8	9	10
Penicillin	38.4	38.0	37.8	37.8	37.8	37.6	37.6	37.6	37.4	37.4
No antibiotics	38.5	38.1	38.1	37	37.6	37.6	37.5	37.4	37.5	37.4

Complications

See Table 2. The most common complication of a hip replacement is infection. In the eleven hips we have reported on, the infection rate was 18 per cent. This is a high incidence.

This infection rate is high. In the eleven hips we have reported on, the infection rate was 18 per cent. This is a high incidence.

Table 2. Complications

Case 1	20
Case 2	20
Case 3	20

A Necrosis

1 Case 11221 (per cent slip) reduced with prosthesis. Infection reduction was attempted with antibiotics. Joint space broke off in 2 months. He seen after 10 months. Necrosis surgery seems due to an extensive

2 Case 8332 (per cent slip) placed plugs and osteotomy through the with staples. Osteotomy was displaced. New staples. Necrosis and deformity in 1 and 2 operations on the neck may well

3 Case 8333 10 per cent slip with call into the joint broke and backed into the hip. The patient was a diabetic. Necrosis Cause not clear. This was the only hip of 1 develop necrosis.

4 Case 8466 10 per cent slip with call site not opened. Treated with intertrochanteric through osteotomy site. Necrosis and not clear.

5 Case 8339 30 per cent slip with call

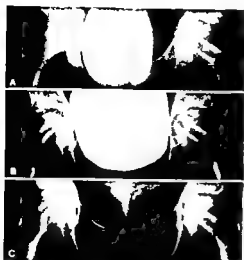


Figure 6 a b c Damage to left head from bone pegs advanced 4 months after operation

sule not opened Treated same as case 8566 Necrosis and deformity in 17 months Cause not clear

6 Case 10325 L 50 per cent slip without callus treated elsewhere with manipulation and S P nail Necrosis and deformity in 1 year Possibly attributed to extensive acute slip and manipulation

Only one case of necrosis no 3 occurred in a case treated by the plugging operation alone in a slip of a mild degree In the 6 cases with necrosis the average time for obliteration of the growth plate was 8.8 months less than the average for the series

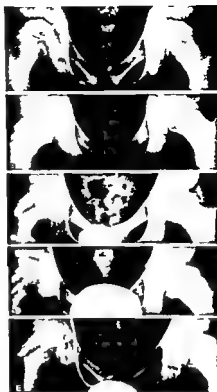
II Direct Mechanical Damage from Plug

In case 8850 L a 15 per cent slip with callus two bone pegs entered the acetabular cartilage Free movement in the joint immediately after operation was recorded Damage to the dome of the head was suggested 2 months later and advanced in 4 months See Figure 6 This was a complication from a technical error With the plug fixed at both ends motion damaged the surface of the head

C Bone Graft Effect Causing Mechanical Obstruction to Joint Motion

Case 5959 which also developed necrosis developed a large mass of bone over the protruding ends of the plugs on the femoral neck This grew to a size where it impinged on the edge of the acetabulum See Figure 7 a-c

Figure 7 a-e Progression of slipping in unsuspected right hip and bone graft effect in plugged left hip The photos are reversed



DISCUSSION

Bone plugging with cortical beef bone in epiphysiolysis is a clinically successful method. The time required for obliteration of the cartilaginous growth plate is diminished though probably not so well as with autogenous cancellous bone. Further slipping has not occurred either in pre operative traction or at any time in the post operative period. One may speculate that drilling across the cartilaginous growth plate alone associated with over 6 weeks of traction might be a successful form of treatment but it seems unworthy of clinical trial.

One patient in this series who underwent simple plugging associated with opening of the capsule developed necrosis. Five other cases that developed necrosis could either be explained by the degree of acute slip could not be explained though *not* treated with the simple plugging operation or in one case the necrosis was probably related to inadequate fixation of a cervical osteotomy.

Two complications were related to positioning of bone plugs and could have been avoided with more careful surgical technique

SUMMARY

A series of 44 hips with capital femoral epiphysiolyis is reviewed most of which were treated by plugging with cortical beef bone plugs

Complications due to the method are described and found for the most part to be avoidable

The method is found to be successful though probably not as fast in causing obliteration of the cartilaginous growth plate as that using autogenous cancellous bone

A valuable roentgenologic diagnostic sign previously described in the literature is emphasized

RESUME

Une série de 44 hanches avec epiphysiolyse de la tête femorale est reexaminée la plupart ayant été traitées par enchevillement avec chevilles d'os cortical de boeuf

Les complications decoulant de la methode sont decrites en demontrant que la plupart peuvent cependant etre evitees

On considere que la methode a ete un succes probablement pas tellement parce qu'elle produit une obliteration de la croissance de la croissance de la plaque cartilagineuse que parce qu'elle utilise de l'os spongieux autogene

Il est souligne comme cela a ete prealablement decrit dans la litterature qu'il est precieux d'avoir un bon diagnostic radiologique

ZUSAMMENFASSUNG

Eine Gruppe von 44 Hüften mit Epiphyseolyse des Femurkopfes wird besprochen. Die Mehrzahl der Hüften wurde mittels Einschlagen von kortikalen Ochsenknochenpflocken behandelt.

Komplikationen, die im Zusammenhang mit der Methode stehen, werden beschrieben und man findet, dass sie größtenteils vermeidbar sind.

Die Methode ist erfolgreich, obwohl sie wahrscheinlich nicht so rasch zur Obliteration der Epiphysenplatte führt als die, welche autogenen Spongiosaknochen verwendet.

Ein wertvolles roentgenologische diagnostisches Zeichen, das früher in der Literatur beschrieben wurde, wird hervorgehoben.

ACKNOWLEDGEMENT

I would like to thank Professor dr med Ivar Alvik for allowing me access to all necessary material at Sophus Munde. To dr Victor Segalstad I am grateful for help in evaluating roentgenograms wherever needed and particularly for calling my attention to the roentgenological sign described here.

REFERENCES

- 1 Capener N (1952) Modern trends in orthopedics (Second Series) Ed H Platt Butterworth & Co Ltd. London
- 2 Durbin F C. (1960) Treatment of slipped upper femoral epiphysis *J Bone Jt Surg* 42B 789
- 3 Heyman C. H. & Herndon C. H. (1954) Epiphyseodesis for early slipping of the upper femoral epiphysis *J Bone Jt Surg* 36A 539
- 4 Howorth B (1957) Slipping of the upper femoral epiphysis *Clin Orthop* No 10 148
- 5 Howorth B (1965) Slipping of the capital femoral epiphysis *Amer J Orthop* 7 10
- 6 Jacobs P (1967) A note on the diagnosis of early adolescent coxa vara (slipped epiphysis) *Brit J Radiol* 33 619

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OSTEOTOMY IN OSTEOARTHRITIS OF THE HIP JOINT

A Follow up Study

By

CARL HIRSCH & JAN GOLDIE

Received 13 II 67

THEORETICAL CONSIDERATIONS

The clinical picture of osteoarthritis of the hip is well recognized and characterized by pain and restriction of motion. At an early stage the symptoms are temporary, later chronic disturbances may cause severe disabilities. The discrepancy between the clinical and radiographic appearance is sometimes striking and the prognosis is hardly predictable (*Danielsson*). Surgical interventions will have to rely entirely on the evaluation of the patient's situation, the need changing for each individual person.

The pathomorphologic features are well recognized: the damage to the cartilage (*Chung*) gives rise to a number of phenomena: osteophytes and subchondral bone disturbances (*Pommer, Lang, Sawyer* and *Ghormley, Trueta*), intraosseous circulatory disorder (*Trueta, Hult*), presence of granulation tissue (*Harrison, Schajowicz, Trueta*) and nerve elements close to erosion areas in the cartilage (*Miller* and *Kasahara*) and inflammatory reaction in the synovial tissues. Some physicochemical properties of blood from osteoarthritic joints have also been claimed to differ from normal (*Kalayama et al*).

There has long been evidence that cartilage can suffer from mechanical forces interfering with the physical properties of the joint surfaces. Inadequate pressure per unit cartilage area causes residual deformations of longer duration. This appears to be the case in joints where incongruency exists (*Wiberg, Hirsch, Steindler*). But even between congruent surfaces some areas are more subjected to pressure than

others. In the hip joint the pressure area is located towards the anterior superior part of the femoral head (*Trueta Frankel Rydell*). This is the place where early pathological changes start (*Trueta*).

All this information has yet not yielded a complete understanding of the mechanism of pain. However, attempts have recently been made to utilize the presence of subchondral tissue reactions with its nerve supply into a theory of pressure sensitive areas (*Hirsch*). Force measurements obtained from a replacement femoral head prosthesis indicated the magnitude and direction (*Rydell*). The findings suggested that the compression area of the femoral head hardly escaped mechanical strain. Walking at an increasing speed increased the force while the use of a cane and slow movements gave a marked relief. Once the compression area due to its pathology has become increasingly sensitive clinical symptoms appear. It then seems logical to look for measures by which the pressure should be decreased or distributed in other ways. Allowing sensitive areas to escape to a certain extent the mechanical strain.

Clinical experience from various surgical interventions may well fit into such a mechanical way of explaining favourable results. Since the stress distribution is a function of body weight and the anatomical shape of the upper femur and muscle action, procedures such as myotomies, tenotomies or neuretomies will alter the mechanical conditions. A similar result might arise if the anatomical relationships are altered by an intertrochanteric osteotomy. Both these procedures, muscle release and osteotomy, might introduce other areas as pressure zones where none or less sensitive bone destruction is present. If the pressure zone on the femoral head as indicated above is rather limited, the degree of clinical result in terms of less pain would then depend upon the type of pathology that is introduced to take over the mechanical strain. Early interventions, that is to say, in less advanced cases with good mobility, would adjust the joint preoperative limitation of movement may not.

Other theories trying to explain the effect of osteotomy take into consideration not only changing but mainly increasing the area of weight bearing whereby the pressure per unit area decreases (*Pauwels*). This leads to different types of angulation osteotomies based on mainly the evaluation of the X rays.

CLINICAL MANAGEMENT AND REPORTED RESULTS

To achieve a reduction of compressive forces upon the joint Pauwels stated that a release of musculature acting on the joint should be performed. Moreover a procedure increasing the weight transmitting area of the articular surfaces which consequently should reduce the pressure per unit area in the joint should also be carried out. By an intertrochanteric osteotomy with upward and medial displacement of the femoral shaft as described by McMurray the adductors and hip extensors muscles are claimed to relax and thus the reduction of muscular force on the joint is obtained. The weight transmitting area is however not changed and accordingly an additional procedure has to be done which entirely depends on the preoperative position of the femoral head. If on radiographs it is estimated that to increase the weight transmitting area it becomes necessary to turn the head medially an adduction osteotomy is performed. If however a lateral tilt of the head is required to increase the weight bearing area an abduction osteotomy is carried out. In both procedures internal fixation is made. In more than 400 osteotomies done according to the above principles Pauwels (1951-1963) found the results most reliable permanent and in many cases surprisingly good.

Muller Nissen Harris and Kirwan among others reporting very good results advocate intertrochanteric osteotomy with internal fixation in cases of hip joint osteoarthritis. According to these authors post osteotomy radiological improvement has shown that osteotomy can produce arrest and partial healing of the disease. In consequence it was therefore suggested (Nissen) that osteotomy be carried out at a much earlier stage. This assumption has been substantiated by the investigation of Harris and Kirwan who compared the results of osteotomy in two series of patients the one having osteotomy early (58 years or less 90 degrees flexion no radiographic evidence of collapse of bone) the other late (65 years flexion reduced to between 60 and 90 degrees without collapse of bone or 90 degrees flexion but some collapse of bone). They found that early osteotomy seldom fails to give relief of pain (95 per cent) and that in 70 per cent convincing evidence of regression indicating arrest of the arthritic process was obtained. Improved function of the joint followed this investigated and proved by Shepard.

During recent years the operative technique has varied. These have been

a discussion as to how the osteotomy should be performed. The devices for internal fixation have also changed. We have only recently adopted compression methods. Certainly the procedure can be further improved.

It is obvious that surgery when discussed in terms of redistributing acting mechanical forces does not consider all the pathoanatomical conditions that may be of importance. However many of the reports mention not only freedom of pain and improved function but also effects on the postoperative radiographic appearance claiming that the osteoarthritic process in itself can be repaired. It is often claimed that other than pure mechanical events follow osteotomies such as improved circulation and favourable metabolic effects.

In trying a surgical procedure it is certainly important to justify the intervention by pathophysiological explanations but this is not enough to encourage the use of the method unless the results from a pure therapeutic point of view satisfy the patient. In this report we have therefore restricted ourselves to see what we have accomplished clinically.

In 1960 one of us (*Hirsch*) studied the results obtained in late osteoarthritis by intertrochanteric osteotomies. Complete relief of pain was obtained in only 30 per cent but 80 per cent claimed an improvement. The mobility of the hip joint did not increase and the radiographic appearance did not alter. As other reports have mentioned good results both clinically and radiographically we thought it necessary to reconsider the problem and therefore we carried out a follow up examination of osteotomized patients from 1961 through 1963. Our main interest was centered on the following questions:

Age at onset of disease

Age at osteotomy

Functional and sociomedical disturbances preoperatively

Type of internal fixation of osteotomy and its influence on the postoperative process

The influence of the time for postoperative mobilization on end result

Complications with regard to type of internal fixation

Overall end results of osteotomy

pain

mobility

walking

work capacity

radiographic appearance

PRESENTATION OF MATERIAL

Age Distribution and Joint Affections

The material for this investigation consisted of 114 operated patients during the years 1961-1965. The 114 patients represented 123 operated hip joints. Of these 102 were personally investigated by either one of us during 1966-1967.

Table 1 Operated hip joints

Operated hip joint	Male	Female	Total
Right	24	36	60
Left	28	35	63
Total	52	71	123
Both	3	1	

In 6 females and 3 males both hip joints were operated. As is noticed there is an overrepresentation for females 58 per cent compared to 42 per cent for the males but the distribution of side is fairly equal.

The distribution of age and sex (Table 2) in this material follows what is commonly reported in the literature (McMurray Gade Pauwels, Harris and Kirwan, Milch Tillberg). The ages varied from 40 to 78 years with an average of 59.6 years for the males and 53.1 years for the females.

Table 2 Distribution of age and sex of patients at time for osteotomy

Age	Male	Female	Total
40-50	10	12	22
50-60	21	20	41
60-70	20	18	38
70-80	4	10	14
Total	54	60	114

The age at which the first symptoms appeared in the patients is shown in Table 3.

The predominance for females in the younger age periods is noted. As is seen in Tables 2 and 3 the material contains patients with early

osteoarthritis which from the point of view of age can be well compared with the cases of early arthritis reported by *Harris* and *Kirwan* in whose early group the average age was 58 years and in the late group 65. The length of history before operation was also ascribed some importance by *Harris* and *Kirwan* who found that for the early group it was 4 years and 9 months and for the late 6 years and 3 months. In our series the length of history before operation was three and a half years for the 40-50 year group six and a half to seven years for the 50-60 year group and about ten years for the 60-70 year group.

Table 3 Period of age for appearance of symptoms

Age	Male	Female	Total
40-50	11	19	30
50-60	30	34	64
60-70	13	7	20
Total	54	60	114

All patients in this material presented osteoarthritis which in 91 patients was primary and in the remaining secondary to other structural joint abnormalities (Table 4).

Table 4 Structural joint changes prior to osteoarthritis

Structural change	Male	Female	Total
Congenital dislocation	1	11	12
Dysplasia	1	3	4
Perthes disease	4	—	4
Epiphyseolysis	1	1	2
Trauma	1	2	3
Total	6	17	23

COURSE OF DISEASE

The history of most patients was rather uniform though two definite types could be detected. One was a group of patients who had continuous suffering with constant weight bearing pain and pain at rest. They amounted to 72. The other group had considerable suffering though of an intermittent type with short periods of alleviation. This was en-

countered in 42 patients. The daily activities of most patients were strongly limited due to the considerable pain which in many cases did not recede despite rest and analgesics. In 16 patients however some form of activity was necessary for the alleviation of pain the most common being continuous flexion movements in the affected hip-joint. Most patients experienced pain on standing, walking, sitting, and lying in bed. Prior to osteotomy hospital admission for various types of therapy—including operative—had been necessary for 31 patients of which no less than 15 had been subjected to such surgical measures (Table 5).

Table 5. Types of surgical procedure in hip joints prior to osteotomy

Surgical procedure	Male	Female	Total
Loss operation	2	3	5
Excision of obturator nerve	2	5	7
Coagulation of vessels and nerves	1	—	1
Osteomyelotomy	—	1	1
Total	5	10	15

Long term stays in convalescent homes were common and previous surgery had in all instances been followed by conservative treatment like that which patients had received who had not undergone surgery such as physiotherapy (88 patients), baths (37), X-ray treatments (57), intra-articular injections (44) and medicines of various types. Of these acetylsalicylic acid was the most common (97 patients) and generally formed the basic drug which was supplemented periodically by other adjuvants such as morphine and derivatives (10 patients), muscle relaxants (10), antiphlogistic agents (17) and sedatives (8).

As the sick history of all patients had lasted for some years before the osteotomy they had had time to adjust themselves to the ailment and the limitations it imposed on their mobility and daily activities. The condition immediately prior to operation was in general good. 109 patients could look after themselves and partake in easier home life activities without too great difficulty. The work capacity on the other hand was very limited and at the time of operation only 33 were fully at work.

OPERATIVE PROCEDURE AND POSTOPERATIVE COURSE

Number of Osteotomies and Methods

The operative method was mostly an intertrochanteric osteotomy with internal fixation according to *Kessel*, *Tupman Blount* or *Wainright* respectively. In some cases no internal fixation was used. The number of osteotomies and choice of method are represented in Table 6.

Table 6 Osteotomies during 1961-63 and choice of method

Year	Choice of method										Total
	Kessel		Tupman		Blount		Wainwright		Other		
	M	F	M	F	M	F	M	F	M	F	
1961	-	1	3	4	1	-	3	9	-	-	21
1962	3	2	9	4	-	1	6	4	2	-	31
1963	-	2	2	3	1	1	9	9	-	-	27
1964	-	-	1	-	-	-	7	21	-	-	29
1965	-	-	-	2	-	-	7	6	-	-	15
Total	3	5	15	13	2	2	32	49	2	-	103

M = male F = female

Incision

As for the soft tissue technique a few variations were employed the importance of which became evident in the immediate postoperative course. The incision was in most cases (116) directed obliquely from the anterior superior iliac spine to the trochanter and then continued distally for some 15 cm. In the remaining seven a straight vertical incision above and below the trochanter was used. The tensor fasciae latae was in all cases incised along the fibre direction and then cut at a right angle below the greater trochanter to release tension. The vastus lateralis was in 23 cases dissected free from its origin at the greater trochanter and gently pushed anteriorly. In 73 cases the same muscle was split in the middle along the fibre direction. No information was given as to muscular incision in the remaining 27 operations.

Osteotomy

The osteotomy was performed above the lesser trochanter in 111 cases right through it in 5 and below in 7. The shaft of the femur was dis-

placed medialward. The degree of medial displacement as judged by radiographs was 2 ± 0.5 cm.

The instruments by which the osteotomies were carried out varied but on further investigation it did not become evident that either procedure had any influence on healing, stability, contact of resection areas or later course. It was for some time thought that the use of a high speed electric saw might cause a necrosis of bone due to the emission of heat but this could in no way be proved. In 13 cases an ordinary chisel was used, in 91 an electric saw and in 19 a Gigli saw.

Fixation

It was thought very important at the time of operation to achieve as stable a fixation and as good a bone contact as possible. In 95 cases the fixation was considered stable, in 4 rather dubious and in 2 very bad. Information about the remaining 22 is lacking. The two cases with bad fixation healed completely in due course. In these series compression devices were not applied.

The osteotomy contact was good in 90 cases, acceptable in 29 and bad in 4. In two of these in which the contact was bad pseudarthrosis developed but on the other hand delay in union (see Table 15) occurred in cases where the surgical procedure was thought to be adequate.

Postoperative Immobilization

The postoperative immobilization was in the beginning of the period very rigid with the patients in a hip spica for some 4-6 weeks. This was used in 25 patients. The remainder only had a pillow in bed abducting their legs. The time in bed postoperatively differed greatly depending on varying opinions on early activity. The mean value of number of days spent in bed was 18.1 ± 10.5 . The standard deviation is no doubt great but easily explicable by the fact that it was believed that the stable fixation and good osteotomy contact were sufficient to justify early rising from bed. As will be noticed in the paragraph on complications this policy was not remunerative in the long run.

Mobilization

Postoperative mobilization i.e. walking exercises after termination of bedrest was carried out in different stages the first being walking without weight bearing on crutches, the second weight bearing with

crutches and finally the third free walking. The mean value in days of the first period was 16.8 ± 2.4 . Those patients who no longer needed crutches or canes postoperatively stopped using them about the fifth month postoperatively.

Postoperative Complications

Immediate complications postoperatively were clinically manifested thrombosis and wound infection. The criteria for the former group were elevated pulse rate and temperature and calf tenderness; for the latter group discharge from the wound with positive bacterial growth on culture. The observations are listed in Table 7 and divided into groups according to method used.

Table 7: Immediate postoperative complications

Complication	Kessel = 8	Tupman = 25	Blount = 4	Wainwright = 81	Other = 2	Total = 123
Clinically manifested						
thrombosis	~	7	~	25	1	33
Infection	2	3	~	6	1	12

Because of the different sizes of the groups representing various fixation techniques a comparison of the frequencies becomes futile. Certain conditions predisposing to thrombosis may, however, be mentioned e.g. age and nutritional state of patient, technique of incision and the surgical wound behaviour, postoperative haematomas, type of immobilization, time for institution of and energy of physiotherapy, period of bedrest and preoperative use of anticoagulants. In our series we noted a slight tendency to high thrombosis frequency in those cases where the vastus lateralis had been split lengthwise through the muscle mass. Thrombosis was also met frequently in those patients who were postoperatively immobilized in plaster. The observations, however, are made on too small a material to become significant but may nevertheless serve as a possible explanation for the formation of thrombosis. The rate of infection is higher than is commonly seen in a surgically treated material but the true culprit besides the bacteria is difficult to pursue. Most of these followed an innocent course excepting one patient who died from general sepsis.

FOLLOW UP

The follow up was carried out during 1966 and 1967 thus with a longest observation time of 5 years and a shortest of 18 months. Of the 114 operated patients 102 were followed up. 12 could not be examined for various reasons as seen in Table 8. Each patient was personally approached by one of us and questioned according to a special questionnaire and also physically examined. The number of followed up hips was 110 as seen in Table 9.

Table 8. Reasons for exempted follow up

Reason	Male	Female	Total
Death			5
Cancer	1	-	
Circulation	1	2	
Postop sepsis	1	-	
Living abroad	1	-	1
Not traced	1	2	3
Refusal to present at follow up	1	2	3
Total	6	6	12

Table 9. Followed up hip joints after osteotomy

Operated hip joint	Male	Female	Total
Right	21	33	54
Left	25	31	56
Total	46	64	110

12 patients representing 13 hip joints have not been followed up

Table 10. Spontaneous pain

	Male	Female	Total
Improved	40	45	85
Unchanged	1	4	5
Deteriorated	5	7	12
Total	46	56	102

Table 11 Weight bearing pain

	Male	Female	Total
Improved	33	38	71
Unchanged	5	11	16
Deteriorated	8	7	1
Total	46	56	102

The relevant questions for the follow up in this investigation were a) spontaneous pain b) weight bearing pain c) mobility from subjective and objective points of view d) walking capacity e) work capacity and f) general subjective evaluation

Mobility

This was indicated in two ways the first being, the patient's subjective evaluation of his postoperative mobility. Great importance was paid to the patient's own estimation of his ability to put on and take off shoes to tie shoestrings to put on stockings to sit comfortably both at home and in cars and finally to climb tramcars and buses. The results are seen in Table 12

Table 12 Subjective evaluation of postoperative hip joint mobility

	Male	Female	Total
Improved	21	16	37
Unchanged	6	20	26
Deteriorated	17	22	39
Total	44	58	102

The second way of approach was an objective estimation of the difference in mobility before operation and after operation. At this investigation the length of the lower limb was measured. The following variables were thus studied and the values before and after operation compared: length of lower limb, flexion, adduction, abduction, outward rotation and space inward rotation. The distribution of frequency for each quality is seen in Figures 1-7

The values have been subjected to statistical analysis according to Student's *t* test. The test has been carried out on the 5 per cent level

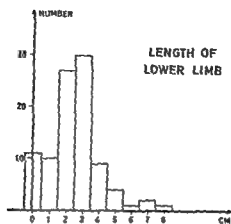


Fig 1

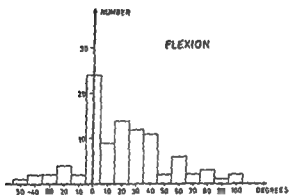


Fig 2

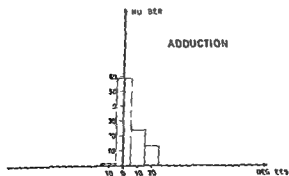


Fig 3

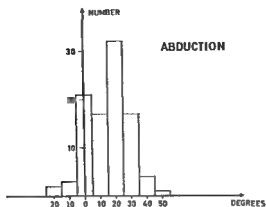


Fig 4

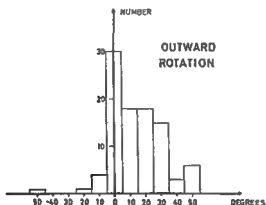


Fig 5

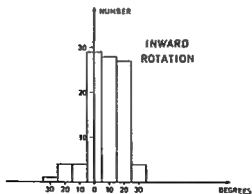


Fig 6

Summarizing the analysis it can thus be said that the difference of values before and after operation are significantly greater than zero i.e. all variables show less values after operation. On the 5 per cent level the following results were obtained

Length of lower limb	difference is between 2 and 3 cm		See Figure 1
Flexion	10	20	" "
Adduction	0	5	3
Abduction	10	20	4
Outward rotation	10	20	5
Inward rotation	0	10	6

Walking Capacity

This was mostly dependent on the use of a cane. Therefore it was thought appropriate to estimate the ability for walking in correlation to the use of the cane pre and postoperatively as shown in Table 13.

Table 13 Walking capacity as related to the use of cane

	Before operation	After operation	
		with cane	without cane
Use of cane	65	55	10
No use of cane	35	25	17

In judging the walking ability of osteotomized patients it soon becomes evident that the true nature of their gait is not disclosed unless a very penetrating interrogation is tactfully carried out. To many the use of a cane becomes such an ingrown habit that walking with it is not looked upon as an aid to facilitate each individual step. On attempting to walk without a stick the patient however becomes aware of the difficulties her gait then gives her. The most common factors met in this material were the weightbearing pain and the limp secondary to the shortening of the lower limb. Indoor walking was easier than outdoors and on interrogation it was found that the patients generally walked with the aid of chairs, tables and other objects in the home which could give some support. It was surprising to find how many patients (32) had a scheduled route to follow on moving from one part of the home to the other.

Work Capacity

On perusing the material in general the following results were obtained Table 14 which is a rough estimate of the patients own opinion of their capacity to carry out work with which they had preoperatively been occupied or a new occupation into which they had been introduced postoperatively

Table 14 Work capacity

	Male	Female	Total
Improved	15	21	36
Unchanged	10	22	32
Deteriorated	19	15	34
Total	44	58	102

Complications

The complications met in the later postoperative course were pseudarthrosis and fracture of the instrument for internal fixation Table 15

Table 15 Late postoperative complications

Complication	Heise = 8	Furman = 23	Blount = 4	Wainwright = 81	Other = 2	Total = 123
Pseud arthrosis	1	3	1	11	-	16
Fracture of fixation instrument	2	2	-	3	-	7

The rate of pseudarthrosis seems at least partly to be related to the length of postoperative stay in bed

Thirteen of the total 16 pseudarthrosis cases had postoperative immobilization in bed of considerably shorter duration than the mean average This was estimated at 181 days with a deviation of ± 105 days The thirteen pseudarthrosis cases remained in bed for 9-12 days

All pseudarthrosis cases were reoperated In ten of these the non united area was bonegrafted In the remainder the area was drilled Fifteen have healed completely whereas one despite bonegrafting remained nonunited

The fractures of the fixation instrument were interpreted as metal

fatigue. Some patients whose osteotomies had satisfactorily healed experienced pain of another type than that of osteoarthritis. It became evident that the internal fixation instrument could cause discomfort and therefore the fixation material was extracted in a number of cases as seen in Table 16.

Table 16 Extraction of fixation instruments due to pain

Kessel = 8	Tupman = 28	Blount = 4	Wainwright = 81	Total = 123
3	14	1	14	32

All these patients were relieved of their pain after extraction.

Subjective Evaluation

How the patients experience the operation and how they appreciate their postoperative condition is seen in Table 17.

Table 17 Subjective evaluation of postoperative condition

	Male	Female	Total
Satisfied	38	43	81
Not satisfied	15	6	21
Total	53	49	102

Thus the great majority was satisfied with the results of the operation despite weightbearing pain, certain limitation in daily activities, minor decrease in mobility and limp on the operated side. On further analysis it became evident however that the greatest appreciation was due to the abolition of spontaneous pain. The patients could enjoy a night's good sleep without being disturbed by pain and sitting was no longer an obstacle in social life. The appreciation of this was so great that other discomforts secondary to operation were almost ignored.

Radiographic Appearances

We have tried to evaluate the radiographs. The pictures vary to a great extent and there is very little correspondence between what could be

seen on X ray and the clinical results. Rarely did the joint space increase nor did sclerosis or cystic formations disappear.

SUMMARY

On 114 patients with osteoarthritis of the hip joints 123 hips were operated with intertrochanteric displacement osteotomy and internal fixation according to Kessel, Tupman, Blount or Wainwright.

A follow up was carried out 18 months—3 years following surgery in 102 patients representing 110 hips. Good results were obtained in 82.3 per cent. The improvement was most pronounced in patients with constant pain at rest.

Weight bearing pain was diminished in 72.5 per cent but a majority had to use a cane postoperatively.

The mobility had improved or remained unchanged in 64.7 per cent but deteriorated in 38.2 per cent.

Pseudarthrosis was encountered in 13 per cent and all have been reoperated with a good result excepting one patient.

The technique used ended with the neck of the femur in varus. Shortening of the lower limb was seen in all patients and experienced as great discomfort.

It is felt that improved internal fixation offering more accurate and reliable fixation should decrease the rate of pseudarthrosis and unexpected positions.

RESUME

Chez 114 malades souffrant d'ostéoartrite de l'articulation de la hanche 123 hanches ont été opérées par déplacement intertrochanterique ostéotomie et fixation interne selon Kessel, Tupman, Blount et Wainwright.

Un examen a été pratiqué entre 18 mois et 5 ans après l'intervention chirurgicale chez 102 malades représentant 110 hanches. De bons résultats ont été obtenus dans 82.3 pour cent des cas. L'amélioration a été la plus marquée chez les malades qui avaient des douleurs constantes même au repos.

La douleur provenant du port du poids du corps a été diminuée chez 72.5 pour cent mais une majorité des malades ont été obligés de se servir d'une canne après l'opération.

La mobilité s'est accrue ou est restée inchangée dans 64.7 pour cent.

des cas mais elle a été diminuée dans 38.2 pour cent. On a rencontré une pseudarthrose dans 13 pour cent et tous ces cas ont été réopérés avec un bon résultat à l'exception d'un seul malade.

La technique utilisée a abouti au placement en varus du col du fémur. Un raccourcissement du membre inférieur a été constaté chez tous les malades ce qui est ressenti comme un grave inconvénient.

On a l'impression qu'une fixation interne améliorée comportant une fixation plus minutieuse et plus stable devrait pouvoir diminuer le nombre des pseudarthroses et les positions anormales.

ZUSAMMENFASSUNG

Bei 114 Patienten mit Arthrosis deformans der Hüftgelenke wurden 123 Hüften mittels intertrochanterer Verschiebungsosteotomie und interner Fixierung nach Kessel, Tupman, Blount und Wauright operiert.

Eine Nachuntersuchung wurde 18 Monate bis 5 Jahre nach der Operation an 102 Patienten mit 110 Hüften durchgeführt. Gute Ergebnisse wurden in 82.4 Prozent erhalten. Die Besserung war im meistenten bei Patienten mit konstanten Ruheschmerzen ausgesprochen.

Belastungsschmerzen waren bei 72.5 Prozent verringert, aber die Mehrheit musste nach der Operation einen Stock gebrauchen.

Die Beweglichkeit war in 64.7 Prozent gebessert oder unverändert geblieben, war jedoch in 38.2 Prozent verschlechtert.

Pseudarthrose wurde bei 13 Prozent angetroffen und alle diese wurden abgesehen von einem mit gutem Ergebnis reoperiert.

Die verwendete Technik endete mit dem Schenkelhals in Varusstellung. Verkürzung der unteren Gliedmasse wurde bei allen Patienten beobachtet und wurde als grosse Belästigung empfunden.

Man ist der Meinung, dass eine verbesserte interne Fixation die eine genauere und verlässlichere Ruhigstellung darbietet, das Vorkommen von Pseudarthrosen und unerwünschten Stellungen herabsetzen sollte.

REFERENCES

- Blount W. (1952) Proximal osteotomies of the femur. Instructional course lecture. *Amer. Acad. Orthop. Surg.* 11: 1.
- Blount W. (1964) Osteotomy in the treatment of osteoarthritis of the hip. *J. Bone Jt. Surg.* 46 A: 1297-1325.
- Chrisman O. D., Fessel J. M. & Southwick W. D. (1963) The effects of cartilage homogenates and their components on peripheral joint structures. *J. Bone Jt. Surg.* 45 A: 1541.

- Chung E. H. (1966) Aging in human joints *J nat med iss.* 58 2
- Danielsson L. G. (1964) Incidence and prognosis of coxarthrosis *Acta orthop scand* Suppl 66
- Frankel V. (1960) The femoral neck. Almqvist & Wiksell Boktryckeri AB Stockholm
- Gade H. G. (1947) A contribution to the surgical treatment of osteoarthritis of the hip joint. *Acta chir scand* Suppl 120
- Harris V. & Kirwan E. (1964) The results of osteotomy for early primary osteoarthritis of the hip *J Bone Jt Surg* 46 B 477-487
- Harrison M. H. M., Schajowicz F. & Trueta J. (1963) Osteoarthritis of the hip. A study of the nature and evolution of the disease *J Bone Jt Surg* 35 P 4
- Hirsch C. (1944) The pathogenesis of chondromalacia of the patella *Acta chir scand* Suppl 83
- Hirsch C. (1960) Inter-trochanteric osteotomies in osteoarthritis of the hip *Acta orthop scand* 30 199-136
- Hirsch C. (1966) Stress strain and sensory mechanism in painful hips. Steindler Award Lecture *J Bone Jt Surg* 48-A
- Hulth A. (1968) Circulatory disturbances in osteoarthritis of the hip *Acta orthop scand* 28
- Katayama R., Itami Y., Hasegawa Y., Inoue T., Honma M., Yonemoto K., Nakagawa I., Kawata T. & Yamashita Y. (1965) Pathology and clinic of osteoarthritis of the hip *Tokyo jikeikai medical journal* 80
- Lang F. J. (1934) Arthritis deformans und Spondylitis deformans. Handbuch der speziellen pathologischen Anatomie und Histologie. Henke Lubarsch, IX 2 p 954
- Lloyd Roberts C. C. (1963) The role of capsular changes in osteoarthritis of the hip joint *J Bone Jt Surg* 35 B 697
- Lindström N. (1950-51) Arthroplasty and arthrodesis in arthrosis deformans coxae. A post investigation *Acta orthop scand* 20 249
- McFarland B. L. (1977) Osteoarthritis of the hip. 7e Congres International de Chirurgie Orthopédique p 811 Brussels. Imprimerie des Sciences
- McMurray T. P. (1935) Osteoarthritis of the hip joint *Brit J Surg* 22 716
- Matsumoto Y. & Mizuno S. (1966) Rate of the blood flow in the femoral head. A new measuring procedure and its clinical evaluation *Med J Osaka University* 18 4
- Miller M. R. & Hashihara M. (1963) Observations on the innervation of human long bones. *Anat Rec* 145 1
- Milch H. (1965) Osteotomy of the upper end of the femur. The Williams and Wilkins Co. Baltimore
- Müller M. E. (1957) Die hüftnahen Femurosteotomien 151 Stuttgart Georg Thieme Verlag
- Nissen K. I. (1960) The arrest of primary osteoarthritis of the hip *J Bone Jt Surg* 42 B 473
- Nissen K. I. (1963) The arrest of early primary osteoarthritis of the hip by osteotomy *Proc roy Soc Med* 56 1051-1060
- Nissen K. I. (1964) Un cas d'ostéarthrite primitive débutante de la hanche traité par ostéotomie avec déplacement minime *Acta orthop belg* 30 651-667
- Pauwels F. (1973) Basis and results of an etiological therapy of osteoarthritis of the hip joint. IVème Congres de la Société Internationale de Chirurgie Orthopédique et de Traumatologie Tom II pp 31-50 Wien

- Pommer G (1913) Mikroskopische Befunde bei Arthritis deformans Mitteilungen aus dem Pathologisch Anatomischen Institut der k. k. Universität Innsbruck
- Pommer G (1927) Über die mikroskopischen kennzeichen und die Entstehungsbedingungen der Arthritis deformans *Virchows Arch f path Anat* 263 431
- Rosborough H & Stiles P J (1966) The problem of union following intertrochanteric osteotomy with internal fixation for osteoarthritis of the hip *J Bone Jt Surg* 48 B
- Rydell N (1966) Forces acting on the femoral head prosthesis *Acta orthop scand* Suppl 88
- Sawyer M H & Shormley R H (1941) Pathologic study of hypertrophic arthritis of the hip *Surgery* 11 381
- Shaw N W & Harris N (1960) Treatment of osteoarthritis of the hip by myelotomy A preliminary report *Proc roy Soc Med* 53 949
- Shepard M M (1960) A further review of the results of operation on the hip joint *J Bone Jt Surg* 42 B 177
- Steindler A (1955) Kinesiology of the human body Charles C Thomas Publisher USA
- Tillberg H (1966) Resultat av intertrochantär valgusosteotomi vid höftarthros Nord Ortop Forening Göteborg Juni 1966
- Trueta J (1963) Studies on the etiopathology of osteoarthritis of the hip *Clin orthop* 31 7-19
- Trueta J & Harrison M H M (1953) The normal vascular anatomy of the femoral head in adult man *J Bone Jt Surg* 35 B
- Trueta J & Lima C. (1959) Ageing and osteoarthritis *Geront Clin* 1
- Wiberg G (1939) Studies on dysplastic acetabula and congenital subluxation of the hip joint with reference to the complication of osteoarthritis *Acta chir scand* Suppl 57
- Wiberg G (1941) Roentgenographic and anatomic studies on the femuro patellar joint *Acta orthop scand* 12

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ACTIVE-EXTENSION CAPACITY OF THE KNEE JOINT IN THE HEALTHY SUBJECT

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It is usually assumed that a person in good sound health can actively extend the knee joint through the full range with the possible reservation of a slight resilience due to stretching of the posterior articular capsule if a powerful attempt is made to extend the joint passively. In earlier papers the authors have examined the forces acting in the knee-joint in active extension (2) and measured the force exerted by the quadriceps in the healthy subject (3). It was found that near full extension it was difficult if not impossible to obtain a reliable determination of the position of the knee joint by ordinary clinical methods and it was necessary to resort to radiographic examination.

In connection with these studies it was found surprisingly enough that healthy subjects in the supine position with the leg raised from the table were unable to extend the knee joint fully. In passive extension with the foot supported and the leg hanging freely and relaxed there was a further 5° of extension on average and in some cases as much as 10°. With the object of further examining this active extension defect we have carried out a more systematic study on a series of knee joints.

MATERIAL

The study was performed on 52 subjects with sound knees: some of them hospital staff and others patients admitted for disorders not concerned with the lower extremities. The age and sex distribution is shown in Table 1. The term "sound knee" as used here implies that the knee joint was clinically normal, that there were no symptoms associated with the knee and that a radiographic examination of the joint did not disclose pathologic alterations apart from mild arthrosis.

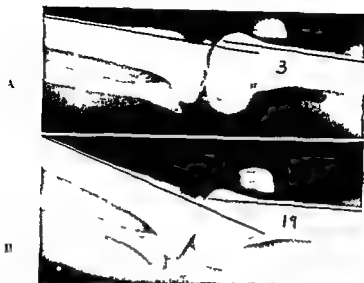


Figure 1 The knee joint in lateral view. The reference lines for the femur and tibia are drawn in A. Full passive extension (zero position). B Full passive extension with the leg horizontal. In this case the active extension defect was unusually large (16°) and was obvious on clinical investigation.

METHODS

The extension position of the knee joint was determined on X-ray films. Lateral projections were taken with a focus to film distance of 100 cm. As a reference line the anterior contour of the femur or tibia was used (Figure 1). Maximum extension (the reference position) in this connection is defined as the position obtained with the patient supine and the leg horizontal with a support under the foot and a load of 5 kg over the knee joint. The degree of flexion was measured from this reference position.

The following positions of the knee joint were examined:

- (1) Supine with the leg relaxed and supported under the foot with a load of 5 kg applied over the knee joint (the weight was hung in a sling)
- (2) Supine as in (1) but with a weight of 3 kg
- (3) Supine as in (1) but with a weight of 1 kg
- (4) Supine as in (1) Fully relaxed but with no load
- (5) Supine but with full active extension of the knee which is raised from the table unsupported. When the exposure was made the patient was asked to extend the knee joint as much as possible
- (6) Standing with full active extension of the knee unsupported

In a further 14 subjects 7 and 9 kg loads were used to see whether there would be further extension beyond the reference position.

Table 1 *Distribution of subjects with respect to age and sex*

Age	20-29	30-39	40-49	50-59	60-69	Total
Men	1	5	3	11	9	32
Women	1	1	2	5	5	20
Total	2	10	5	16	14	57

Table 2 *Flexion of the knee joint in various positions in a comparison with full extension defined as the position with a load of 5 kg over the knee joint and the muscles relaxed*

	Flexion (°)	
	Mean	Range
Supine relaxed load 5 kg	0	
Supine relaxed load 3 kg	0.6	-1 to +3
Supine relaxed load 1 kg	1.1	-1 to +4
Supine relaxed load 0 kg	2.4	+1 to +5
Active extension standing	3.9	+1 to +7
Active extension supine	5.1	0 to +19

RESULTS

The mean flexion and the ranges for the various positions are presented in Table 2. A reduction of the load on the knee from 5 to 3 kg gave extremely little flexion. The difference was not significant. With a load of 1 kg there was slight flexion that was significantly different from the reference position (0°); the effect was still more pronounced with no load at all.

In the 10 cases loaded with 7 and 11 kg, there was on average an extremely small additional extension (not significant).

In full active extension in the erect position there was a mean flexion of 3.9° and in full active extension in the supine position (when the weight of the lower leg contributes to the flexion) the flexion position was still greater—on average 5.1°—the differences were significant (0.05). It is remarkable that in several subjects the active extension deficit in the supine position was more than 10° and in one case as much as 19°. It was then possible even with the ordinary clinical methods to see that full active extension was not achieved.

DISCUSSION

The earlier observation that active extension of the knee could not always be achieved completely in the supine position with the leg raised was verified by this study. What are the causes of this relative insufficiency? In earlier studies by Lindahl & Movin (2) and Hallén & Lindahl (1) on the forces acting in the knee joint in extension and on the causes of active extension defects in various knee injuries it was found that the lever action of quadriceps at terminal extension became increasingly less favourable. As it is known that a muscle exerts a lower force within its inner path of contraction (von Schönn *et al.*) these two facts would explain the difficulty of obtaining full active extension. In active extension in the supine position with the leg raised from the table the weight of the lower leg acts in the direction of flexion and this may contribute to the extension defect. In the same test in the vertical position this weight does not act and the tone and elasticity of the flexor muscles will then possibly be the only residual factor that counteracts full extension. An impression of the magnitude of this flexing force is obtained from the change in extension achieved with different loads in the supine position with the knee supported but relaxed. Practically full extension could be obtained with as small a load as 3 kg while a load of 1 kg did not suffice to overcome the resistance due to the tone and elasticity of the flexors.

The difference of 2 kg is enough to overcome the tone and elasticity of the flexors and represents a supplementary force of the order of 40 kgf cm acting as a moment (the distance from the knee to the point of support in the proximal and distal direction is assumed to be about 40 cm). The difference in the moment required to obtain full active extension in the horizontal and erect positions is for a normal person on average 100 kgf cm, this value which may be ascribed to the weight of the lower leg gives an impression of the magnitude of the force that the quadriceps can not exert in extension. With for instance a flexion of 120° the quadriceps in the sound knee develops on average a moment of 2200 kgf cm. From these measurements it may be concluded that the muscular power of the quadriceps in extension is about one twentieth of that in flexion and if account is taken of the unfavourable lever action in extension the absolute force for the quadriceps in extension will be only about one fifteenth of that in the 120° position.

There were large individual differences in the recorded values for 0

out of 52 subjects the active extension defect was only 1 or 0. In these cases there was thus no active extension defect of practical significance and then the power exerted by the quadriceps in extension is presumably much greater. This individual variation may account for the relative ease with which some subjects could perform full extension in quadriceps exercise after knee injuries or operations.

SUMMARY

Fifty-two normal knee joints were examined by radiography to determine accurately the position of the joint in *full active extension* compared with various positions of passive extension. There was a mean of active extension defect of 5.1° in the knee joint compared with a passive extension obtained by loading the joint with 3-5 kg and supporting the foot. It is concluded that the power of the quadriceps for further extension in positions of extension is too low (less than 100 kgf/cm) to overcome the resistance presented by the tone and elasticity of the flexors.

RESUME

Cinquante-deux articulations normales du genou ont été examinées par radiographie pour déterminer avec précision la position de l'articulation *en pleine extension active* par comparaison avec des positions variées d'extension passive. Il y avait une extension active défectueuse de 5.1° en moyenne dans l'articulation du genou comparée à l'extension passive obtenue par une charge de 3 à 5 kg sur l'articulation ayant aussi à supporter le poids du pied. On en conclut que la puissance du quadriceps pour une plus grande extension dans les positions d'extension est trop faible (inférieure à 100 kgf/cm²) pour affronter la résistance opposée par le tonus et l'élasticité des fléchisseurs.

ZUSAMMENFASSUNG

Zweifundzig normale Kniegelenke wurden mittels Röntgenstrahlen untersucht um die genaue Position des Gelenkes *bei voller aktiver Streckung* verglichen mit verschiedenen Positionen bei passiver Streckung zu vergleichen. Man findet einen durchschnittlichen aktiven Streckdefekt von 5.1° im Vergleich mit einer passiven Streckung, die man erhielt wenn man das Gelenk mit 3-5 kg belastete und den Fuß unter

¹ kgf = kp = 9.81 newtons = 2.2 pounds of force

stutzte. Man schliesst daraus dass die Kraft des Quadriceps für die weitere Streckung in Streckpositionen zu gering ist (weniger als 10 kgf cm²) um den Widerstand der vom Tonus und der Inaktivität der Flexoren ausgeht wird zu überwinden.

REFERENCES

- 1 Hallén I G & Lindahl O (1967) Muscle function in knee extension *Acta orthop scand* 38 431-444
- 2 Lindahl O & Movin A (1967) The mechanics of extension of the knee joint *Acta orthop scand* 38 296-334
- 3 Lindahl O, Movin A & Ringquist I (1966) Knästräckningens mekanik *Nord Med* 73 898

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HAEMANGIOMA OF THE KNEE JOINT

By

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Haemangiomas are vascular malformations which usually develop during early childhood. They are fairly common on the limbs but seldom involve the joints.

According to their situation the haemangiomas affecting the region of the knee may be divided into juxta articular situated outside the joint capsule but in relation to it, intra articular situated within the joint capsule and intermediate which are of an intra as well as extra articular situation (7-10). The intra articular and intermediate haemangiomas generally involve the synovial membrane.

The first case of synovial haemangioma was described by *Bouchut* in 1856 (1). In 1939 *Bennett & Cobey* (2) on the basis of the 29 cases published up till then could distinguish between two types of synovial haemangioma: diffuse and circumscribed. The diffuse type usually consisted in a cavernous haemangioma giving rise to the typical intermittent pain and swelling in the joint. Circumscribed haemangiomas were often in the form of a pedunculated synovial tumour and of the capillary type. Episodes of locking were characteristic. In 1959 *Lewis, Coventry & Soule* (9) published 11 cases treated in the Mayo Clinic during the period 1907 to 1956. Their findings confirmed in all essentials *Bennett & Cobey's*. The total number of published cases now numbered 58.

Since that time another 17 synovial haemangiomas have been reported (1, 6, 7, 8, 10-17) bringing the total up to 75. Of these haemangiomas 1 affected the elbow joint, one the ankle joint (9) while the remaining 73 were situated in or at the knee joint.

It is the object of the present paper to report another 7 cases of synovial haemangioma in the knee joint and 12 cases of juxta articular

haemangioma at the same joint. The symptoms and signs in the two groups, the differential diagnosis and the treatment will be discussed.

MATERIAL

During the period 1937 to 1966 operations were performed on 19 haemangiomas in the region of the knee.

In 7 cases the haemangioma involved the synovial membrane. In one of these cases the haemangioma was intra articular and in 6 cases intermediate.

In 12 cases the haemangioma was juxta articular.

Out of the 7 synovial haemangiomas 4 were found in females and 3 in males. Out of the 12 juxta articular ones 3 affected females and 9 males.

Table 1 gives the patients' ages at the first symptom. It will be seen that the complaints started with almost equal frequency all through childhood. However 3 of the juxta articular haemangiomas did not give rise to symptoms until the patients were 16, 30 and 44 years of age.

Table 1 Age at onset of symptoms in 19 cases of knee joint haemangioma

	Total number of cases	<1 year	1-5 years	6-10 years	11-15 years	>15 years
Synovial haemangioma	7	2	1	2	2	0
Juxta articular haemangioma	12	1	2	4	2	3

Table 2 The clinical features of knee joint haemangioma

	Total number of cases	Mean duration of symptoms when first seen	History of trauma	Pain and swelling	Intermittent symptoms	Locking
Synovial haemangioma	7	4 years	2	7	6	1
Juxta articular haemangioma	12	3 years	3	8	8	1

From Table 2 it is apparent that the nature of the symptoms was approximately the same whether or not the haemangiomas involved the synovial membrane and in both groups the patients had been suffering from the symptoms for an average of 3-4 years when they were referred to us. It must be mentioned, however, that intermittent pain and swelling in the joint were present in nearly all the synovial haemangiomas, while these symptoms were less common in the juxta articular haemangiomas. Two patients had a history of locking. One proved to have a diffuse

synovial haemangioma the other one a juxta articular haemangioma localized beneath the vastus medialis. The aetiology of the locking is obscure.

The physical signs are listed in Table 3. In 2 of the synovial haemangiomas there was swelling of the joint which was never present in juxta articular haemangiomas. In addition pain and limited mobility were considerably more common in synovial haemangiomas. In the only case where a juxta articular haemangioma gave rise to limited motion there was a question of a large haemangioma in the vastus medialis and this caused a moderate restriction of flexion. Of the 4 cases where a synovial haemangioma restricted the mobility this restriction was moderate in 3 cases while in one it was pronounced owing to violent destructive osteoarthritis in the joint. Muscular atrophy was also a relatively common finding in synovial haemangioma. In most of the patients a mass was palpable in the region of the knee. As a rule the masses were soft and ill defined. Among the synovial haemangiomas a palpable mass was present in 4. Two of these masses were tender. In juxta articular haemangioma there was a palpable mass in 8. 3 were tender. In 3 instances the tenderness was not present especially on a level with the mass being more diffuse in the region of the knee.

Table 3 The physical signs of knee joint haemangioma

	Total number of cases	Joint swelling	Pain on motion	Limitation of motion	Mass	Tenderness	Muscle atrophy	Haemangioma elsewhere	Leg length discrepancy
Synovial haemangioma	7	2	5	4	4	4	5	3	1
Juxta articular haemangioma	10	0	6	1	8	4	4	2	2

X-ray examination in 7 cases of synovial haemangioma revealed 10 phleboliths. In one of the 6 cases there was also destruction of the joint, particularly marked in the medial tibial condyle (Figure 1). In one case there was a translucency in a femoral condyle and in one case there was periosteal reaction distally on the femur. Among the 12 juxta articular haemangiomas there were 1 phleboliths and periosteal reaction distally on the femur in one (Figure 2), destructive changes in a tibial condyle in one and periosteal reaction distally on the femur in one.

At operation the haemangioma was in all 7 cases localized at the site of the named radiographic changes.

Arteriography was performed in 6 cases. In 3 it revealed haemangioma in the knee region and in one also arteriovenous anastomosis in the same region.

Ilethbography was carried out in 2 cases. In one it showed intra articular haemangioma (Figure 3).

In the present series the diagnosis was made preoperatively in 3 out of the 7 cases of synovial haemangioma and in 4 out of 12 cases of juxta articular haemangioma.

Operation disclosed 7 synovial haemangiomas, one of which was in the form of a



Figure 1 Synovial haemangioma with phleboliths and joint destruction

Figure 2 Juxta articular haemangioma with phleboliths and peristernal reaction

Figure 3 Phlebography of intra articular haemangioma

circumscribed intra articular non pedunculated synovial tumour while 6 were intermediate haemangiomas of the diffuse type penetrating the joint capsule and spreading without any sharp demarcation into the surrounding tissue. In 4 cases they involved the quadriceps muscle, in 2 only the skin and subcutaneous tissue. While the circumscribed haemangioma could be removed radically without any difficulty, this was not possible in the case of the 6 diffuse ones. In one of these cases there was violent destruction of the joint and arthrodesis was performed.

Operation disclosed 12 juxta articular haemangiomas in an extra articular situation but in relation to the knee joint capsule. 7 of these haemangiomas were circumscribed while 5 were diffuse. Out of the diffuse haemangiomas 3 involved the quadriceps muscle, 1 the popliteal bursa and 1 exclusively the subcutis. In this group too radical surgery was possible only in the case of circumscribed haemangiomas.

On pathological examination 5 out of the 7 synovial haemangiomas including the circumscribed one could be classified as cavernous, 1 was capillary and 1 a fibrillar haemangioma cavernosum. Out of the 12 juxta articular haemangiomas 11 were examined histologically and all were found to be of the cavernous type.

The postoperative follow up period for synovial haemangiomas ranged from 3 months to 12 years, average 3 years. There have been two recurrences. One occurred about 10 years after the operation and was re-operated with a good result. The other recurrence appeared 4 years after the operation and was treated with X-rays. The patient has now been symptom free for 2 years.

The juxta articular haemangiomas have usually been followed for a few months after the operation so that it is not possible to assess the recurrence rate.

DISCUSSION

Synovial as well as juxta articular haemangiomas are rare and this is no doubt the explanation why they are so seldom diagnosed pre-operatively in spite of the characteristic syndrome. In the present material for instance synovial haemangiomas were diagnosed pre-operatively in only 8 out of 7 cases and in *Lewis, Coventry & Soule's* series in 3 out of 11 cases (9).

With the present material the total number of published cases of synovial haemangiomas is brought up to 82. It is worth noting that in 80 of these cases the haemangioma has affected the knee joint.

The typical patient with synovial haemangioma is a child who has for some years had intermittent pain and swelling of a knee joint. The symptoms are usually not preceded by trauma. In most cases a soft diffuse and at times tender mass is palpable in the region of the knee. As a rule there is pain on moving the joint and often a somewhat restricted mobility. Muscle atrophy is a common finding. Not infrequently there are haemangiomas of the skin in other sites. X-ray examination occasionally shows phleboliths and possibly destructive changes or periosteal reaction of the bone at the site of the haemangioma. Articular destruction also occurs.

The symptoms and signs of juxta articular haemangioma do not differ much from the above description and often the differential diagnosis with a view to the localization of the haemangioma in relation to the synovial membrane causes difficulties. If there is swelling in the joint and in particular if joint puncture yields blood the haemangioma of course involves the synovial membrane. In the event of considerably restricted motion and muscle atrophy there is presumably also a question of synovial haemangioma. Otherwise the only means of determining the accurate site of the haemangioma in fairly early cases is arteriography or phlebography.

If there is an arteriovenous shunt in connection with the haemangioma the limb on the affected side may be lengthened and the symptoms and signs on the whole characterized by the increased arteriovenous flow. It is of the utmost importance to diagnose such shunts preoperatively. Therefore arteriography should invariably be done if there is a suspicion of haemangioma. Plethysmographic investigation too will frequently afford valuable preoperative information (4).

In respect to the prognosis in untreated cases it is of essential importance that owing to the ever recurring haemorrhage in the joint

the synovial haemangioma may lead to considerable destruction in the joint similar to that seen in haemophilic patients (2). The present material includes one such case in which the articular destruction was so advanced that arthrodesis had to be done.

Accordingly the synovial haemangiomas should be treated at a stage as early as possible. In juxta articular haemangiomas the indication is not quite so clear and in the event of mild symptoms it may be justified to await spontaneous remission.

In circumscribed haemangiomas radical surgery is possible and in these cases surgery gives good results (9). In diffuse haemangiomas radical operation is very difficult (2). The present material includes 11 haemangiomas of the diffuse type and none could be treated radically. In diffuse haemangiomas therefore X ray irradiation is indicated postoperatively or as the only treatment (2, 3). In the present material one recurrence of synovial haemangioma was successfully treated by X ray irradiation.

SUMMARY

During the period 1937 to 1966 a total of 19 cases of haemangioma in the region of the knee were treated by operation. 7 haemangiomas involved the synovial membrane. In 18 cases microscopic examination of the haemangiomas was done. One was classified as capillary whereas the remainder were of the cavernous or predominantly cavernous type.

The typical symptoms and signs of synovial and juxta articular haemangioma are described (Tables 1, 2 and 3).

In localized haemangiomas surgical treatment gives good results but in the diffuse cases radical surgery is seldom possible. In such cases X ray irradiation is used either postoperatively or as the only treatment.

RÉSUMÉ

Au cours de la période 1937 à 1966 un total de 19 cas d'hémangiome dans la région du genou ont été traités chirurgicalement. 7 hémangiomes atteignaient la membrane synoviale. Dans 18 cas il a été effectué un examen microscopique de l'hémangiome. 1 un a été classifié comme capillaire alors que tous les autres étaient du type caverneux ou avec prédominance du type caverneux.

Les symptômes typiques et les signes d'hémangiome synovial et juxta articulaire sont décrits (Tableaux 1, 2 et 3).

Lorsque l'hémangiome est localisé le traitement chirurgical donne

de bons resultats mais dans les cas diffus une intervention radicale est rarement possible. Dans ces cas on a recours a l'irradiation aux rayons X soit apres l'operation soit comme unique traitement.

ZUSAMMENFASSUNG

Während des Zeitraumes 1937 bis 1966 wurden insgesamt 19 Fälle von Hämangiom der Knieregion operativ behandelt. 7 Hämangiome umfassten die Synovialmembran. In 18 Fällen wurde eine mikroskopische Untersuchung des Hämangiomes vorgenommen. Eines wurde als Kapillärhämangiom klassifiziert während die übrigen von kavernöser oder vorherrschend kavernöser Type waren.

Die typischen Symptome und Zeichen von synovialen und juxta artikularen Hämangiomen werden beschrieben (Tabelle 1 II und 3).

Bei lokalisierten Hämangiomen führt die chirurgische Behandlung zu guten Ergebnissen. In diffusen Fällen ist radikale Chirurgie jedoch nur selten möglich. In solchen Fällen wird Röntgenbestrahlung entweder postoperativ oder als alleinige Behandlung verwendet.

REFERENCES

1. Aret W. (1958) A case of hemangioma of the knee capsule. *Chir Var ad Ruchu Ortop Pol* 23: 177.
2. Bennett C. E. & Cobey M. C. (1939) Hemangioma of joints. *Arch Surg* 38: 487.
3. Bertels G. (1953) Beitrag zur Kenntnis der Hämangiome des Kniegelenks. *Zbl Chir* 78: 711.
4. Bertelsen A. & Dohn A. (1953) Congenital arteriovenous communications of the extremities. *Acta chir scand* 105: 443.
5. Doucloul E. (1956) Tumeur erectile de l'articulation du genou. *Ga Hop (Paris)* 29: 349.
6. Brodsky A. E. (1956) Synovial hemangioma of the knee joint. *Bull Hosp Joint dis* 17: 58.
7. De Palma, A. & Mauler G. C. (1961) Hemangioma of synovial membrane. *Clin Ortop* 20: III.
8. Kristó B. & Horvath, G. (1959) Hemangioma of knee joint. *Zbl Chir* 84: 501.
9. Lewis, R. C., Coventry M. B. & Soule E. H. (1959) Hemangioma of the synovial membrane. *J Bone Jt Surg* 41 A: 264.
10. Mastragostino M. & Fares C. C. (1959) Synovial hemangioma of the knee. *Riv anat pat oncol* 11: 874.
11. Palmer I. (1966) Synovial hemangioma i knäleden. *Nord Med* 76: 893.
12. Papadia L. & Cognallo R. (1960) Angioma della sinoviale del ginocchio. *Minerva ortop* 11: 23.
13. Randelli M. (1961) An angioma of the synovial membrane. *Arch Ortop (Milano)* 74: 333.

- 14 Rinaldi C. & Veneroni G (1960) Osservazioni su di un caso di angioma del menisco del ginocchio *Minerva ortop* 11 149
- 15 Schechter D C. (1961) Intra articular hemangioma of the knee *Arter Surg* 27 638
- 16 Skwarcz A (1960) A case of angioma of the knee joint *Chir Var ad Richu Ortop Pol* 25 509
- 17 Stauber H (1957) Hemangioma of the prepatellar bursa *Zbl Chir* 87 1409
- 18 Van den Berg A (1951) Een geval van haemangiomatosis diffusa synovial genus sinistri *Ved T Geneesk* 93 985

From the Orthopaedic Hospital Aarhus Denmark
(Heads Professor E. Thomasen MD and J Haugmann-Jensen MD)

ARTHROGRAPHY IN MENISCAL INJURIES OF THE KNEE JOINT

By

JØRGEN SØMDER

Received 18 xi 66

Meniscal injury is still a diagnostic problem and the value of arthrography as a supplementary diagnostic procedure in clinically doubtful cases is still a matter of discussion. On the other hand it seems to be widely agreed that arthrography is unnecessary when the clinical diagnosis seems obvious.

The object of the present study was (1) to investigate the accuracy of the arthrographic diagnosis in a material of clinically doubtful cases of meniscal injury and (2) to ascertain whether the diagnostic accuracy is altered by supplementing the clinical investigation by arthrography in clinically doubtful cases.

PRESENT INVESTIGATIONS

In the Orthopaedic Hospital Aarhus Denmark operation is performed without previous arthrography if the clinical diagnosis is "certain" i.e. the history and the physical findings make the diagnosis of meniscal injury very likely. In clinically doubtful cases preoperative arthrography was performed up to 1963 but the operative indication was not based solely upon the arthrographic findings.

The arthrographies were carried out in the Radiological Department of the Aarhus County Hospital and the reports from the radiologists formed the sole basis of whether the arthrographies were considered positive or negative. A positive arthrography is taken to mean that the report indicates an injury or a suspicion of such injury. A negative arthrography is taken to mean that according to the report the appearances are normal.

During the period 1960-1962 arthrography was performed on 166

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- 16 Skwarcz A (1960) A case of angioma of the knee joint *Chir Var ad Ruchu Ortop Pol* 25 509
- 17 Stauber H (1957) Hemangioma of the prepatellar bursa *Zbl Chir* 82 1409
- 18 Van den Berg A (1931) Een geval van haemangiomatosis diffusa synovial genus sinistri *Ned T Geneesl* 95 985

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During the period 1960-1962 arthrography was performed on 166

patients in whom the clinical diagnosis was doubtful. Arthrographies carried out on other indications e.g. a suspicion of a meniscal remnant left by previous meniscectomy, loose body or the like were excluded.

Of these 166 patients 98 had operations. The preoperative arthrographic findings and operative results are shown in Table 1.

Table 1 Preoperative Arthrographic Findings Compared with the Operative Findings

Preoperative arthrographic finding	Number of cases	Operative finding		Percentage of arthrographic error
		Injury	No injury	
Injury	54	37	17	31
No injury	44	23	21	52

Table 2 Result of Follow Up on the Non Operated Patients Compared with the Arthrographic Findings

Arthrographic finding	Number of cases	Followed patients		Not followed
		Injury	No injury	
Injury	4		2	2
No injury	64	8	56	6

It will be seen that out of 54 positive arthrographies 17 were incorrect i.e. a percentage of error of 31. Out of the negative arthrographies 23 of 44 were incorrect a percentage of error of 52. Thus in cases where it was possible to check the arthrography by operation there was a total error in the preoperative arthrographic diagnosis of 40 per cent in cases of clinically doubtful meniscal injuries. It should be pointed out that the error is most pronounced in cases of negative arthrography.

Out of the remaining 68 who did not undergo operation 64 had negative while 4 had positive arthrographic findings. Out of these 4 patients 1 refused to have an operation. The other 3 were asked to present themselves for operation but failed to come. Of the 68 patients 33 have been followed up for an average of 4 years (1 year 3 months to 6 years 6 months). Eighteen patients have been followed up for such a long time that according to the data in the records further follow up is not necessary. The average follow up period for these 18 patients is 18 months (6 months—4 years). Out of the remaining 17 I have been in touch with 11 by telephone or letter. All reported that they were symptom

tion was based solely upon the arthrography however they found an error of 26 per cent. Therefore their findings too cannot be taken to indicate that arthrography increases the diagnostic accuracy.

CONCLUSION

It is obvious that the question whether the history and clinical findings indicate operation in the individual cases must vary appreciably from surgeon to surgeon. Considering however the marked arthrographic error in clinically doubtful cases the only conclusion that can be drawn is that the arthrographic inaccuracy is as great as the clinical inaccuracy and that—as also demonstrated in the present study—the diagnostic accuracy is independent of whether or not arthrography is done preoperatively.

SUMMARY

This is a report on a 3 year material comprising 166 patients with clinically doubtful meniscal injuries who underwent arthrography. The arthrographic findings were checked at operation or at follow up of the non-operated patients. The accuracy of the arthrographic diagnosis is discussed.

To ascertain whether the clinical diagnosis can be altered by doing preoperative arthrography in clinically doubtful cases two 2 year operative series were compared. In one arthrography was done preoperatively in cases where the clinical findings were doubtful while in the other series no arthrography was done.

It is concluded that the inaccuracy of the arthrography is as great as that of the clinical examination and that the clinical diagnosis is independent of whether or not arthrography is performed preoperatively.

RESUME

Compte rendu d'un matériel d'observation examiné pendant une période de 3 ans et comprenant 166 malades avec lésions méniscales cliniques douteuses demandant une arthrographie. Les trouvailles arthrographiques ont été vérifiées à l'opération ou par des examens complémentaires chez les malades non opérés. Il est discuté de l'exactitude du diagnostic arthrographique afin de voir si le diagnostic clinique peut être altéré lorsqu'on pratique l'arthrographie. Les cas douteux ont été comparés à deux séries opératives de 2 ans. Dans l'une l'arthrographie avait été pratiquée avant l'opération dans des cas où les trouvailles cliniques

étaient douteuses alors que dans l'autre série il n'avait pas été fait d'arthrographie.

Il est conclu que le manque d'exactitude de l'arthrographie est aussi grand que celui de l'examen clinique et que le diagnostic clinique n'a aucune dépendance du fait que l'arthrographie a été pratiquée ou non avant l'opération.

ZUSAMMENFASSUNG

Dies ist Bericht über ein 3 jähriges Material das 166 Patienten mit klinisch zweifelhaften Meniskusschäden an denen eine Arthrographie vorgenommen wurde umfasst. Die arthrographischen Befunde wurden mit denen bei der Operation oder bei der Nachuntersuchung der nicht operierten Patienten verglichen. Die Genauigkeit der arthrographischen Diagnose wird erörtert. Um festzustellen ob die klinische Diagnose in zweifelhaften Fällen mittels Arthrographie verändert werden kann wurden zwei 2 jährige operative Gruppen miteinander verglichen. In der einen wurde eine präoperative Arthrographie vorgenommen in Fällen wo die klinische Diagnose zweifelhaft war während in der anderen keine Arthrographie ausgeführt wurde. Man kommt zur Schlussfolgerung dass die Ungenauigkeit der Arthrographie ebenso gross wie die klinische Untersuchung ist und dass die klinische Diagnose unabhängig davon ist ob eine Arthrographie vor der Operation ausgeführt oder nicht ausgeführt wurde.

REFERENCES

- 1 Andersen Kjeld (1948) Pneumoarthrography of the knee joint *Acta orthop scand suppl* 4
- 2 Antoine M J Lesure & J J Creusot (1955) L'arthrographie du genou par contraste opaque *J Radiol Electrol* 36 915
- 3 Bohr H (1959) On the diagnosis of the meniscus in the knee with special regard to the value of arthrography *Acta orthop scand* 29 140
- 4 Jensen S Borup & I Thestrup Andersen (1952) Arthrography as a diagnostic aid in lesions of the knee joint *Acta chir scand* 103 309
- 5 Lindblom K (1948) Arthrography of the knee *Acta radiol suppl* 74
- 6 Oggioni G Ref Excerpta medica
- 7 Saugmann Jensen J (1963) Knæets menisklæsioner Munksgaard Copenhagen
- 8 Sevastikoglou J (1954) Diagnostik vid mediale meniskskador *Nord med* 53 1047
- 9 Turner V C & F Brown Wurtz (1959) Arthrography in the diagnosis of meniscal injuries of the knee *J Bone Jt Surg* 41 A 1914
- 10 Wagner Aage (1952) Is pneumoarthrography necessary for the diagnosis of meniscus lesions *Acta radiol* 37 399
- 11 Wurdinger H & O v Kanel (1964) Der Wert der Doppelsontrastarthrographie des Kniegelenkes in der Meniscuschirurgie *Der Chirurg* 5 212

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OPERATIVE TREATMENT OF ANKLE FRACTURES

By

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Received 27 iv 67

The present study is a continuation of an investigation in which a series of ankle fractures from the period 1950-1963 were studied (Solonen & Lauttamus 1965). Our aim is now to assess the value of operative treatment.

MATERIAL

During the period 1964-1965 all together 489 patients with ankle fracture were treated at our Clinic. This figure does not include outpatients.

The fractures are classified according to Lauge Hansen Palmer in Table 1.

Sex

There were 236 males and 253 females.

The different types of fracture were evenly distributed between both sexes with the exception of the SE group which comprised 141 females and 103 males.

Age

The patients' ages ranged from 11 to 86 years.

The average age of the males was 36 that of the females 38.

Nature of Accident

The accidents are classified according to type in Table 2.

Slipping or stumbling cause the highest number (60 per cent) of SE fractures. In traffic accidents, particularly when the patient had been hit by a motor vehicle or had fallen from his motor-cycle, I and S fractures were the commonest.

Treatment

Treatment was operative in 310 cases (72 per cent) and conservative in 179 (28 per cent).

At follow up we found that 75 (54 per cent) of the patients treated conservatively should have been treated surgically and that 12 patients (4 per cent) who had been operated on should have received conservative treatment.

Table 1 Classification of injuries

Type	No of patients	%
S I	4	9
S II	41	
SE I	2	50
SI II	14	
SI III	11	
SI IV	217	
P I	72	17
P II	3	
I III	60	
PI III	18	4
PE IV	68	
Irregular	39	6
Total	439	100

Table 2 Nature of the accident in various groups

Group	Slipping or stumbling %	Traffic accident %	Fall or jump %	Miscellaneous %
S	20	45	16	19
SP	96	2	—	2
P	60	22	5	8
IE	80	5	12	3
Irregular	33	10	28	24

Time of Operation

Operation was generally carried out on the day of the injury or the following day. For various reasons (such as late presentation for treatment skin injury attempted conservative treatment) the operation was not done until as much as 3 weeks after the accident.

(The majority of the surgical cases were treated without preceding conservative treatment.)

Operation

The technique varied owing to the large number of surgeons. In the absence of contra indications a tourniquet was used. After reduction the fracture was fixed

with screws in 398 cases but in fracture of the fibula medullary nailing (Rush) was used in 19 cases and in some cases chrome catgut or steel wire cerclage as the only or supplementary fixation. The deltoid ligament was sutured in 35 cases.

After treatment

After the operation plaster was applied up to a level below the knee. The plaster was removed after an average period of 8 weeks. The patients left hospital four to three weeks after the operation. In cases where weight bearing was considered possible the plaster was replaced by a walking cast after 4 to 6 weeks. In other cases, when consolidation was considered reliable. The transsudesmotic screw was removed at the latest after 7 to 3 weeks unprotected weight bearing.

RESULTS

Our assessment is based on the situation when the patient returned to work and on radiographic examination it being too early to say anything definite about the late results.



Figure 1 In S II fracture surgical repair is sometimes the best treatment



Figure 2 A posterior malleolar fracture of the tibia can often not be treated conservatively. Reliable fixation may require two screws

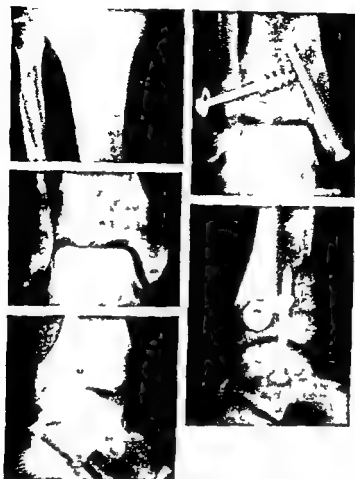


Figure 3 An ankle with a severe P.E. IV injury may appear intact in an antero posterior radiogram. The safest procedure is to fix both the syndesmosis and the malleolus fracture and to suture torn ligaments.
(Lag screw is not advisable)

Grading of the Results

The result was accepted as radiographically good only when there was complete anatomical restoration. Thus no cases with dislocation or angulation of the medial or lateral malleolus were placed in this category. A posterior marginal fragment comprising one quarter or more of the width of the tibia also had to be replaced exactly and no dislocation of the talus was allowed. Fair. No medial or lateral dislocation of the malleolus and no angulation were accepted. Dorsal dislocation of the lateral malleolus should not exceed 2 mm and the large posterior tri-

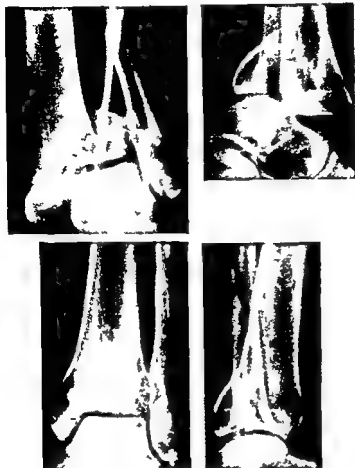


Figure 4 Persistent displacement of the posterior marginal fragment is an unsatisfactory result of conservative treatment of a PE IV injury

angular fragment should not be elevated by more than 2 mm. No dislocation of the talus was allowed.

Results not filling these requirements were recorded as unsatisfactory. Otherwise we followed our earlier grading (1963).

The results in the series as a whole were the same as in our series of 1961-1963: acceptable results (good and fair) 89 per cent, unsatisfactory 12 per cent.

However, if the operatively treated cases (350 cases) are considered separately, we obtain following results: acceptable in 95 per cent (good 76 per cent, fair 19 per cent) and unsatisfactory 5 per cent. In conser-

vatively treated cases the corresponding figures were acceptable in 80 per cent (good 40 fair 40 per cent) and unsatisfactory in 20 per cent

The results of operative treatment in the individual groups are given in Table 3

The results of conservative and operative treatment cannot be compared since in our opinion the method of treatment is decided by the type of the fracture

Of the 13 cases operated upon unnecessarily the result was good in 0 and fair in 3 and unsatisfactory in 1

Table 3 Results in different groups of injury

Group	Total number of operated patients	Results (per cent of total number)		
		Good	Fair	Unsatisfactory
S I	2	100	—	—
S II	26	84	8	8
SE II	9	89	11	—
SE III	8	100	—	—
SE IV	161	70	24	3
P I	18	100	—	—
P II	8	100	—	—
P III	41	78	17	5
PE III	12	75	25	—
PE IV	54	74	13	13
Total	350	76	19	5

Complications

There were no infections of significance. Mild brief infection occurred in the operative wound in 3 cases.

The operation did not delay ossification or cause non union. In the conservatively treated cases there were several cases of non union.

No deaths occurred nor was thrombosis or embolism diagnosed.

Return to Work

The average period during which the patients were incapacitated for work was 4.3 months in conservatively treated cases and 4.5 months in operatively treated cases.

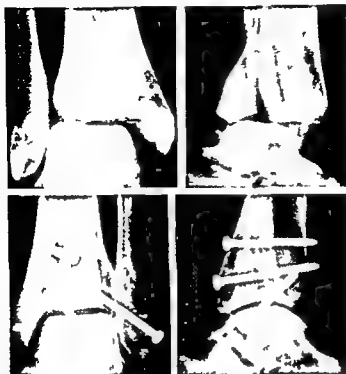


Figure 5 A SE IV injury was treated operatively the fractures were fixed with screws the deltoid ligament and the anterior tibio fibular ligament were sutured (Unnecessary fixation of the lateral malleolus with a transsyndesmotic screw)



Figure 6 In the treatment of a SE IV injury the result shown by an antero-posterior roentgenogram appeared to be good Later a special projection revealed troublesome dislocation of the lateral malleolus



Figure 7 Inadequate treatment The fragment of medial malleolus has not been reduced the talus is laterally dislocated the fragment of the lateral malleolus has been fixed in the wrong position by transsyndesmotic and wrongly directed screws The fragment of the medial malleolus ought to have been reduced and fixed the talus should have been reduced the anterior tibio fibular ligament should have been sutured and after reduction the fracture of the lateral malleolus should have been fixed only to the fibula with a screw or nail

DISCUSSION

Faults in Treatment

Reduction of the lateral malleolus was imperfect in 101 cases. Faulty reduction of the lateral malleolus was the commonest fault in both the conservatively (30 per cent of the series) and the operatively (12 per cent of the series) treated cases. The malleolar fragment remained dislocated proximally, laterally, posteriorly and in outward rotation. A shortened fibula may provoke valgus deformity. The site of the fracture must be exposed. Fixation of the malleolus to the tibia at any rate without exact reduction cannot be regarded as adequate treatment.

A large posterior fragment had remained elevated in 31 cases in 14 of the conservatively and 17 of the operatively treated cases. In 10 of these cases the end result was poor in the rest fair. Operative reduction is not as a rule difficult if the incision is correct but fixation with only one screw is often inadequate. Even after good reduction of a large posterior fragment dorsal flexion of the foot remained limited. In these cases the foot should perhaps be postoperatively immobilized in slight dorsal flexion.

Unsatisfactory reduction or retention of the medial malleolus impaired the result in 12 conservatively and 3 operatively treated cases.



Figure 8 The screw in the medial malleolus introduced at the wrong point and directed wrongly resulting in faulty positioning of the malleolus. The fracture of the lateral malleolus is neither reduced nor fixed.

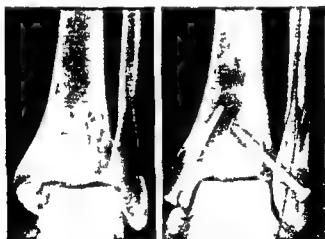


Figure 9 The screw in the lateral malleolus is wrongly directed and pointlessly transsynthetotic.

Pseudarthrosis of the malleolus was seen in 7 conservatively treated cases. This shows that these cases should have been treated surgically. On the other hand, a small avulsion fracture of the malleolus does not by itself require operation. Neither is pseudarthrosis in



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Unsatisfactory reduction or retention of the *medial malleolus* impaired the result in 12 conservatively and 3 operatively treated cases.



Figure 11 Operative treatment of SE IV injury with reduction and fixation of the fracture of the medial malleolus with screws and the fibular malleolus by temporary cerclage the anterior tibio fibular ligament being sutured

such a case a source of inconvenience. Such cases are not included in the above figure. At operative treatment of the medial malleolus periosteal interposition was often seen.

Faulty operative treatment of a *syndesmotic lesion* was apparent in 21 cases: the screw having been left for too long or removed too early. The former caused limited mobility and a *wooden feeling* (Bonnin 1950) or breaking of the screw. After too early removal of the screw the syndesmosis spread in 3 cases, in 1 case even after 9 weeks. In 2 cases the syndesmosis had been too firmly tightened. As a rule the syndesmosis screw had been left in place for 10 to 11 weeks. Fixation of the lateral malleolar fragment with a transsyndesmotic screw in SE and P injuries caused unnecessary traumatization of the syndesmosis. Burwell & Charnley's method (1963) is preferable, but we doubt whether this is sufficient in PE fractures with complete rupture of the syndesmosis. In these cases we consider fixation of the syndesmosis important. Otherwise mono-ossal fixation of fractures with suturation of ruptured ligaments is sufficient.

Non diagnosis or faulty assessment of *ligamental lesions* are among the commonest errors. Lauge Hansen's genetic system clearly shows the nature and extent of the injuries in question. A ligamental lesion is sometimes as important as a fracture. Non suturing of a ruptured deltoid ligament was in our opinion a fault in 28 cases (15 of which had been operatively treated). It is true that insufficiency of this liga-

ment was observed in only 4 cases but healing of the ligament is quicker and more reliable after suturation than after cicatrization. It is impossible for instance without operation to retract the ligament from between the malleolus and the talus where it is sometimes displaced and where it prevents reduction of the talus. Further the posterior tibial tendon may be interposed between the ligament and its insertion. If these possibilities did not exist one could certainly agree with *Bonnin's* (1965) opinion that the bulk of the ligament and its natural form maintain apposition of the torn ends and surgical repair is very seldom needed.

Insufficiency of the lateral collateral ligaments was observed in 3 cases. This injury is rarer in connexion with fractures than with sprain but it must be dealt with. Lesion of the inferior tibio fibular ligament is very common as is clearly and correctly demonstrated by *Tauge Hansen's* classification. It is evident that some of the numerous dislocations of the lateral malleolar fragment result from failure to suture this ligament. Suturation should be done after reduction and fixation of the fracture of the lateral malleolus and it may easily be performed through the same incision.

The *direction and point of entrance of the screw* were often faulty. The site and direction of the screw are of decisive importance in securing the position of the fragment. One cannot simply state that a trans syndesmotic screw from the fibula should be placed horizontally or obliquely. The direction of the screw depends on the individual fracture. It is important that the fracture should be carefully reduced under visual control before fixation otherwise a dislocation will almost always persist.

A screw inserted too close to the cartilage seems to irritate and may even cause nutritional disturbance of the cartilage.

Wrong type of screw. A lag screw is ill suited for these fractures. It is too thick and to tighten it requires so much force that the fragment often turns with the screw. This error had been made in 6 cases.

It is advisable to drill a wide hole for the screw particularly in the medial malleolus. The proximal part of the screw should preferably be without threads. The screw should reach to the opposite corticalis or near it.

Unnecessary operations. With the exception of PE fractures in which operative treatment especially of rupture of the syndesmosis is in our opinion a more reliable procedure than conservative treatment fractures without dislocation should not be repaired surgically. However

OPERATIVE TREATMENT OF ANKLE FRACTURES

whether operation is necessary or not should be decided separately in each individual case and not simply according to type

Operative Technique

The choice of the operative approach has sometimes been faulty. Fracture of the medial malleolus or rupture of the deltoid ligament may well be repaired through a distally curving incision anterior or posterior to the malleolus. A lateral malleolar fracture, the anterior tibio-fibular ligament and the syndesmosis are exposed through an antero lateral incision placed exactly over the syndesmosis.

A posterior marginal fracture is repaired through a postero lateral incision.

Procedure A posterior marginal fracture that requires surgical repair is treated first—with the patient prone—and then the lateral malleolus. In SE fractures the posterior marginal fracture and the fibular fragment constitute an entity united by the ligaments which facilitates reduction. The posterior marginal fragment must often be fixed with two screws for otherwise a primarily good apposition may be lost in the plaster cast.

Closed wound suction is recommended for a period of 1 to 2 days.

Plaster cast should be evenly padded and carefully moulded. The cast must be split anteriorly.

CONCLUSIONS

Since we know that the primary result is generally permanent (Larsen & Laurtzen) and that accurate reduction is the best prophylaxis against arthrosis (Jørgensen 1969, Klossner 1962), rigorous demands must be made on the primary treatment of ankle injuries.

A prerequisite for good results is exact diagnosis which is possible only if the entire mechanism of the injury is fully understood. The Lauge-Hansen genetic classification is the most satisfactory of those known and provides a key to the understanding of the damage as a whole. It must be remembered that the lesion in question is not a fracture of a bone but an injury to a complex weight bearing joint.

It is often impossible to achieve a sufficiently satisfactory result with conservative methods particularly in the treatment of lesions of ligaments and of the syndesmosis but also in fractures of various types. Therefore often consider operative treatment indicated particularly in SE II-IV and PT II-IV injuries. But the indications must be evaluated separately in each case. All significant components of the injury must

be repaired. After exact reduction, firm fixation must be achieved. Together with faulty treatment of ligamentary injuries, unsatisfactory reduction of fracture of the lateral malleolus is one of the commonest faults. The majority of the errors we have detected can be eliminated. We have not observed any disadvantages of operation when it has been indicated and performed with the necessary technical skill.

Convalescence is not significantly longer after operative than after conservative treatment.

SUMMARY

This paper presents 489 patients with ankle injuries treated during a period of two years. 350 patients were treated operatively. Surgical repair led usually to acceptable results (95 per cent). The result would have been better if the whole extent of the injury had been understood in all cases. Technical skill is of high importance in the treatment of these severe injuries.

It is not a question of treatment of a bone fracture but of an extensive joint injury. Syndesmotic and ligamentary lesions should be repaired. Unsatisfactory treatment of these and of fracture of the lateral malleolus are the commonest causes of poor results.

The manifold components of the injury are difficult to repair conservatively. Operation is often indicated and no significant disadvantages of surgical repair were observed in the present series. However, each case must be evaluated separately and classification of the type of injury alone is not a sufficient basis for assessing indications for operation.

RESUME

Cette étude présente 489 malades avec lésions de la cheville traitées durant une période de deux ans. 350 malades ont été opérés. L'intervention chirurgicale a abouti à une proportion élevée de résultats relativement satisfaisants (95 pour cent). Les résultats auraient pu être encore meilleurs si l'on avait compris dans tous les cas l'étendue de la lésion. L'habileté technique est de la plus haute importance dans le traitement de ces graves lésions.

Il n'est pas question du traitement d'une fracture osseuse, mais d'une lésion articulaire étendue. Les lésions syndesmotiques ou ligamenteuses doivent être réparées. Un traitement peu satisfaisant de celles-ci et de la fracture de la malleole laterale sont les causes les plus courantes de mauvais résultats.

Les multiples éléments de la lésion rendent difficile un traitement

conservateur L'operation est souvent indiquee et l'on n'a pas observe dans la presente serie de desavantages provenant de l'intervention chirurgicale. Quoiqu'il en soit il convient d'apprecier chaque cas en particulier et la classification du type de lesion n'est pas a elle seule suffisante comme base d'indication operatoire.

ZUSAMMENFASSUNG

Diese Arbeit stellt 489 Patienten mit Knöchelschäden während eines Zeitraumes von zwei Jahren vor. 350 Patienten wurden operativ behandelt.

Chirurgische Wiederherstellung führte in einer grossen Anzahl zu guten Ergebnissen (95 Prozent). Die Ergebnisse wurden noch besser gewesen sein wenn die Ausdehnung der Beschädigung in allen Fällen ganz verstanden worden wäre. Technische Fertigkeit ist bei der Behandlung dieser schweren Schäden sehr wichtig.

Es dreht sich nicht um die Behandlung eines Knochenbruches sondern um einen ausgedehnten Gelenkschaden. Syndesmose und Bandschäden sollten wiederhergestellt werden. Ungenügende Behandlung derselben und des Bruches des lateralen Knöchels sind die gewöhnlichsten Ursachen von schlechten Ergebnissen.

Die vielfältigen Komponenten der Beschädigung sind schwierig auf konservativem Wege zu behandeln. Operation ist häufig angezeigt und keinerlei Nachteile von Bedeutung wegen des chirurgischen Eingriffes wurde in dem vorliegenden Materiale beobachtet. Jeder Fall muss jedoch separat beurteilt werden und Klassifizierung der Type der Verletzung allein ist keine genügende Grundlage zur Bestimmung der operativen Anzeige.

REFERENCES

- Bonnin J (1950) *Injuries to the Ankle*. Heinemann Medical Books Ltd., London.
- Bonnin J G (1965) *Injuries to the Ligaments of the Ankle*. *J Bone Jt Surg* 47 B 609.
- Burwell H L & Charney A D (1965) The Treatment of Displaced Fractures at the Ankle by Rigid Internal Fixation and Early Joint Movement. *J Bone Jt Surg* 47 B 634.
- Jergesen F (1959) Open Reduction of Fractures and Dislocations of the Ankle. *Amer J Surg* 98 136.
- Klossner O (1967) Late Results of Operative and Non Operative Treatment of Severe Ankle Fractures. A Clinical Study. *Acta chir scand* Suppl 293.
- Lauge Hansen N (1947) *Ankelbrud. I. Genetisk diagnose og Reposition*. Munksgaard, Copenhagen.
- Solonen A A & Laitamus L (1963) Treatment of Malleolar Fractures. *Acta orthop scand* 36 371.

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METABOLIC AND ORTHOPEDIC TREATMENT OF A CASE OF ADULT NONFAMILIAR HYPOPHOSPHATEMIA WITH SEVERE OSTEOMALACIA

By

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The first adult case of the Fanconi syndrome was described by *Stowers & Dent* in 1947 (1). The syndrome consists of osteomalacia with hypophosphatemia, glucosuria, aminoaciduria, and frequently acidosis. There is sometimes a defect in the water retaining ability of the kidney as well. *Wallis & Engle* (2) who reported on eighteen adult cases of the syndrome claimed that multiple familial occurrences are rare in adults whereas a hereditary tendency is common in children with the syndrome.

A condition which shares many features with the Fanconi syndrome is renal tubular osteomalacia in which the serum calcium is usually normal, the serum phosphorus always low, and the alkaline phosphatases increased and in connection with which there is no aminoaciduria and usually no glucosuria. Familial instances of this disease are common but isolated cases also occur. High doses of vitamin D can improve the patient's osteomalacia. The first case of vitamin D resistant osteomalacia is said to have been presented by *Albright et al* in 1937 (3) but the case described by *Milkman* in 1934 (4) which had osteomalacia, hypophosphatemia and glucosuria probably belongs to the group of vitamin D resistant osteomalacia with hypophosphatemia. Most investigators have found a low tubular reabsorption of phosphate in these cases. In children the disorder causes rickets resistant to treatment with vitamin D in doses sufficient to cure nutritional rickets and is therefore often called vitamin D resistant rickets. In adults the hypophosphatemia causes osteomalacia and these adult disorders have

been called phosphate diabetes essential hypophosphatemia idiopathic osteomalacia Milkman's syndrome etc

There seems to be some controversy in the literature with regard to the classification of the various clinical conditions characterized by osteomalacia (or rickets in children) and hypophosphatemia due to decreased tubular reabsorption of phosphate Many textbooks describe the Fanconi syndrome and hypophosphatemic osteomalacia in different chapters (5-6) What seems ultimately to differentiate the Fanconi syndrome from hypophosphatemic osteomalacia is the aminoaciduria which according to most authors is an integral part of the Fanconi syndrome

Dent (7) has suggested a classification of clinical conditions with rickets and osteomalacia from renal tubule defects in six different types According to his classification type 1 denotes osteomalacia in which there is only one human tubular reabsorption defect namely that of phosphate In type 2 renal glucosuria occurs as well The different types of the Fanconi syndrome and hypophosphatemic osteomalacia with renal tubular acidosis are classified as types 3-6 In our opinion this classification is very useful from diagnostic therapeutic and prognostic viewpoints

The main problem with vitamin D treatment in hypophosphatemic osteomalacia lies in the fact that high doses are required in most cases and are accompanied by the constant risk of intoxication with the vitamin It was consequently of great interest when *Fraser* (8) reported in 1957 that intravenous phosphate had a beneficial effect in vitamin D refractory rickets in children In 1958 and 1961 *Frame et al* (9-10) showed that oral phosphate supplement was effective in hypophosphatemic osteomalacia and it was further shown in 1963 by *Wilson & Lendt* (11) that two cases with the adult Fanconi syndrome were improved with oral phosphate treatment alone without vitamin D supplement The role of phosphate therapy in hypophosphatemic rickets and osteomalacia has also been stressed by *Rose* (12) Oral phosphate supplementation is also appealing from the point of view that phosphate administration seems to protect against hypercalcemia of all etiologies (13) and therefore also against the hypercalcemia due to vitamin D intoxication

In the present paper we will report on a case of very severe hypophosphatemic osteomalacia in a man of 27 and the gratifying effect of orthopedic correction in combination with long term treatment with high doses of vitamin D and sodium monophosphate

METHODS

Phosphorus in serum urine feces and food specimens was determined by the method of Fiske SabbaRow (14) Calcium in the same media was estimated with flame photometry Alkaline phosphatase was determined by the method of Bessey Lowry & Brock (15) as modified by Jacobsson (16) Quantitative analysis of the amino acids in the urine was performed by means of an automatic amino acid analyzer (17) as by Spackman Moore & Stein (18) Trace element determinations were performed with a recently developed ion exchange technique with subsequent γ spectrometry (19) after neutron activation

For long periods the patient underwent studies of calcium and phosphorus balance For shorter periods balance studies were also undertaken with respect to 25 different trace elements During the balance study the patient was kept on a constant daily menu that he had chosen himself Feces and urine was collected during five day periods Calcium and phosphorus (and during certain periods trace elements) were determined on aliquots of urine and homogenates of feces The intake of calcium and phosphorus and trace elements was determined by analysis of homogenates of duplicates of each days meals All drugs given were added to the model diet before homogenization The balance data obtained were charted as by Reifenshein *et al* (20)

CASE REPORT

On admission the patient was 26 years old Up to early 1965 he had worked as a mechanic The patient has two brothers and one sister all healthy The father has six healthy brothers and sisters the mother has two healthy brothers and one brother who died from an unknown heart disease at the age of 20

The patient had developed normally as a child and there is no history of rickets

The symptoms started at the age of 16 During 1956-59 there were slowly increasing skeletal pains in the ribs lower back the left knee and the right shoulder but the patient was still able to participate in football and other vigorous activities In 1959 at the age of 19 he called the local hospital and during that year several roentgenograms were taken which revealed fourteen Milkman fractures some in a state of healing others showing no callus In late 1959 the patient developed pains in the hip joints X rays showed fractures in the pelvis ring and in both tibiae and fibulae

In 1959 hypophosphatemia and renal glucosuria were detected and the disorder was considered thereafter to be a Fanconi syndrome The same year treatment with approximately 50 000 IU vitamin D daily was started and was maintained during the four years preceding the development in 1963 of gastric ulcer which led to a Billroth II gastrectomy Thenceforth the vitamin D therapy was omitted for unclear reasons During the period between 1959 to 1963 there were no gross changes in body stature His body height decreased only slightly during this period from 176 to 173 cm There were constant skeletal pains however which were especially severe in the hip joint X ray revealed bilateral Milkman fractures of collum femoris

During 1964 the patient's symptoms did not progress despite the lack of vitamin D therapy

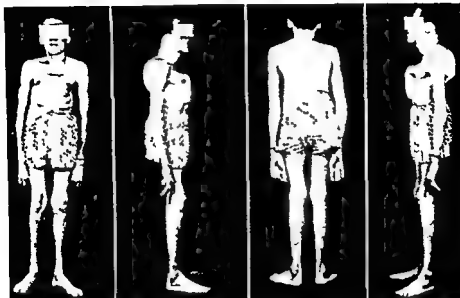


Figure 1 The patient on admission to the metabolic ward

In early 1965 however the symptoms progressed rapidly and within two or three months the patient had developed a severe thoracic kyphosis and the sternum was fractured at a 90° angle. Body height decreased from 173 to 159.5 cm, a dramatic change in three months (Figure 1). Severe pains as well as muscular fatigue in the legs and hip joints bound him to the wheelchair. A compound tablet containing 4,800 IU vitamin D and 600 mg calcium daily was then prescribed but the patient had lost all confidence in doctors and took the tablets only sporadically. He was severely depressed.

The patient was admitted to the metabolic ward Serafimer hospital in January 1966 with the diagnosis of Fanconi syndrome. He was mentally depressed and severely crippled by marked thoracic kyphosis, pigeon chest, generalized muscular weakness and constant skeletal pain. The pains were alleviated by lying down. He could not walk unaided and had for several months required analgesics constantly.

X-ray showed 36 fractures of the Milkman type of variable age as illustrated in Figures 2 and 3. Serum phosphorus was extremely low whereas serum calcium was normal. There was also renal glucosuria but no pathological aminoaciduria. As a result of these findings it was suggested that this was a case of hypophosphatemic osteomalacia with glucosuria, thus being a hypophosphatemic osteomalacia of type II of the Dent classification (1) rather than a Fanconi syndrome. More detailed information on roentgenographic and laboratory findings is given under separate headings later in the text.

After routine examination the patient was subjected to metabolic balance studies during two consecutive 5-day balance periods (10-11a). During the first two control periods he was given the same dose of vitamin D 4,000 IU as pre-



Figure 2 The roentgenogram to the left illustrates the cod fish vertebra typical for advanced osteomalacia. Note the collapse of T6 resulting in a gibbus of approximately 90°. The right figure shows the fracture of the sternum causing pigeon chest.



Figure 3 Roentgenograms showing Millman fractures in the scapulae and in the tibia and fibula before and after metabolic treatment of the osteomalacia. After treatment the fractures are healed.

scribed before admission. During the following periods increasing amounts of vitamin D, calcium and phosphate were given. After five months the medication consisted of 545 000 units of vitamin D₂, 3 g calcium and 15 g sodium monophosphate.

The patient first noticed a decrease in pain after about four weeks of effective treatment. After about two and a half months the muscular weakness and pain

had diminished and the patient was able to walk without walking sticks although he had marked waddling gait. After a few minutes of walking pains would develop in the hips and force him to rest. In late April he was able to be up and about for several hours during the day and experienced pains only in the afternoon. After a little more than five months of a combined regimen of phosphate, calcium and vitamin D, the patient was discharged from the metabolic ward for a planned three months "summer vacation." He was fully mobilized with no pain and scarcely any waddling gait. The patient was optimistic and his depression had vanished. The orthopedic treatment had been quite successful (see under orthopedic treatment); the patient's body height having been increased from 159.5 to 165 cm.

During the summer of 1966 the patient's subjective well being continued and the serum calcium and phosphorus values were normal. In the middle of August however there was a bout of hypercalcemia and the patient was therefore immediately admitted to the metabolic ward. The patient was in excellent condition physically (he was now able to run and to jump from 50 cm heights without pains) and his muscular strength was normal. The vitamin D₂ was omitted for about one month in order to restore normal calcium values. The patient again underwent metabolic balance studies for two and a half months and was discharged in late November. Some adjustment of the medication (see under laboratory findings) was made subsequently and the patient is currently (August 1967) receiving 100,000 units of vitamin D₂ and 15 g sodium monophosphate daily. He is fully rehabilitated and works as an electronic technician.

FAMILY STUDIES

No other case of rickets, osteomalacia or other metabolic bone disease is known in the patient's family. Blood and urine specimens from both parents and all siblings (2 males and 1 female) were investigated for the presence of glycosuria and aminoaciduria and determinations were made of serum concentrations of calcium, phosphorus, creatinine and alkaline phosphatase. All these tests were found to be normal.

EFFECT OF THERAPY ON CALCIUM AND PHOSPHORUS METABOLISM

A few days after admission in January 1966 the patient was put on a balance diet with an intake of exactly 1000 mg calcium and 1100 mg phosphorus. The vitamin D intake was 9,300 I.U. imitating the medication he had taken at home. Only two 3 day control periods were studied due to the patient's poor condition which required treatment. Both calcium and phosphorus balances were negative (see Figure 4) initially, the calcium loss being 120 to 160 mEq per day. The urinary calcium did not exceed 120 mg per day. The phosphorus balance was close to equilibrium and the urinary phosphorus approximately 700 mg per day, a rather normal value.

During the following three balance periods the vitamin D dose was

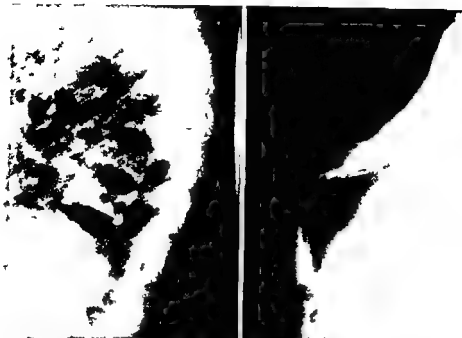


Figure 2 The roentgenogram to the left illustrates the cod fish vertebra type of advanced osteomalacia. Note the collapse of T6 resulting in a gibbus of approximately 90°. The right figure shows the fracture of the sternum causing pigeon chest.



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The patient first noticed a decrease in pain after about four weeks of effective treatment. After about two and a half months the muscular weakness and pain

ance became strongly positive and during one of the two 5 day periods on this regime the calcium balance was positive

During the following six balance periods the treatment was unchanged except for an increase of the calcium intake from 1000 to 3300 mg per day (Calcium Sandoz effervescent tablets). Thereafter the patient was in positive phosphorus and calcium balance. The urinary calcium never exceeded 200 mg per day on this medication but the urinary phosphorus was very high 2500 to 2900 mg.

The serum phosphorus was low despite of the positive calcium and phosphorus balances. The dose of vitamin D₂ was therefore increased from 120 000 to 370 000 units in balance periods 14 and 15 (April) while the phosphate and calcium intakes were unchanged. This normalized the serum phosphorus. The patient was then able to walk without support during short periods and the skeletal pains had decreased. The muscular weakness had improved.

At the end of the third month (balance period 16) the phosphate dose was increased to 1.5 g per day (corresponding to 3 g phosphorus) and with that dose serum phosphorus has been constantly normal. One month later (balance period 2 beginning of May) the dose of vitamin D₂ was further increased to 545 000 units a day. By now the patient was able to move around without crutches or support although he had a typical waddling gait. After 15 minutes or so of walking the patient developed pains in the hip joints and had to rest. At the end of May however muscular strength was nearly normal (as was the electromyogram) and the patient was completely mobilized. There was still a slight waddling gait. The patient left the hospital in the beginning of June after almost six months in hospital. The patient was now in strongly positive calcium and phosphorus balance retaining about 1500 mg of calcium and about 1000 mg of phosphorus. The serum calcium and phosphorus were normal and the extremely large dose of D₂ (545 000 units) had not produced hypercalcaemia.

During two and a half months at home the rather heavy medication was kept constant (545 000 units of vitamin D₂, 3000 mg phosphorus and 2280 mg calcium as tablets). Check ups of serum calcium, phosphorus and alkaline phosphatase and creatinine were made at four week intervals and the urinary calcium was also determined. Physically the patient improved steadily. In the beginning of August however a high serum calcium value (5.7 mEq/l) was seen for the first time and the patient was therefore readmitted to the hospital.

On admission in August 1966 the serum calcium was high 5.7-6.0

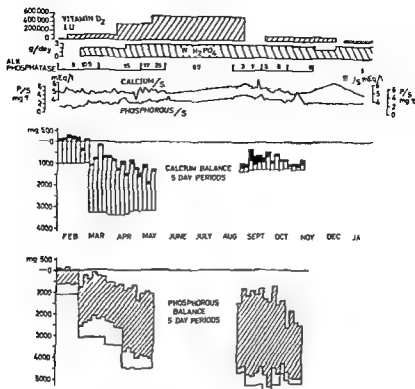


Figure 1. Balance studies of calcium and phosphorus in the patient. Intake is plotted downwards from the base line, output is plotted from the bottom of the intake upwards. The solid and the open parts of the columns represent urinary and fecal excretion respectively. In the case of a positive balance all parts of the columns are below the base line, but if the balance is negative a part of the columns is above the baseline. The figure also shows the alterations in treatment with vitamin D₂, oral phosphate and calcium as well as variations in the serum calcium, phosphorus and alkaline phosphatase.

increased to 120 000 units. That dose of vitamin D obviously failed to change the phosphorus balance and the calcium balance did not become positive. The patient reported no subjective improvement.

During balance periods 6 and 7 sodium monophosphate 10 g per day (corresponding to about 2 g phosphorus) was given orally. The salt was given three times a day in fruit juice and the patient found the taste of this mixture to be acceptable (he has taken it for more than a year now without serious objections). The pH of the divided salt doses in distilled water was 4.8. On the combination of 10 g sodium monophosphate and 120 000 units of vitamin D the phosphorus bal

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At the end of the third month (balance period 16) the phosphate dose was increased to 15 g per day (corresponding to 3 g phosphorus) and with that dose serum phosphorus has been constantly normal. One month later (balance period 2 beginning of May) the dose of vitamin D was further increased to 545 000 units a day. By now the patient was able to move around without crutches or support although he had a typical waddling gait. After 15 minutes or so of walking the patient developed pains in the hip joints and had to rest. At the end of May however muscular strength was nearly normal (as was the electromyogram) and the patient was completely mobilized. There was still a slight waddling gait. The patient left the hospital in the beginning of June after almost six months in hospital. The patient was now in strongly positive calcium and phosphorus balance retaining about 1500 mg of calcium and about 1000 mg of phosphorus. The serum calcium and phosphorus were normal and the extremely large dose of D₂ (545 000 units) had not produced hypercalcaemia.

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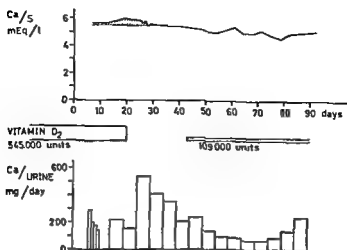


Figure 5 Serum and urinary calcium during a period of slight vitamin D_2 intoxication

mEq/l and the urinary calcium was 294 mg also a high value. The patient's calcium and phosphorus balances were restudied for fifteen 5 day periods. Despite the omission of both vitamin D and calcium the urinary calcium was high for three balance periods (Figure 5). The serum calcium became normal 1–2 weeks after omission of the vitamin (Figure 4). The calcium tablets and all vitamins were omitted for about one month and during this period calcium fell to 5.2–5.5 mEq/l . After four weeks without vitamin D a dose of 100 000 units was instituted. For the ten following balance periods the calcium and phosphorus metabolism was acceptable as judged from the studies of balances and blood chemistry and the patient was discharged for out patient control.

In December 1966 the phosphate intake was lowered to 10 g/day due to the possible interference by oral phosphate with iron absorption (see below). This was followed by a new bout of hypercalcaemia (Figure 4). After 10 days omission of D and reinstitution of 15 g phosphate/day a lower dose of 45 000 units of D was begun.

EFFECT OF TREATMENT ON TRACE ELEMENT BALANCES

The balances for the following trace elements were determined before (balance period 1) and during (period 22) treatment. As Br , Cd , Co , Cr , Cs , Cu , Fe , Hg , Rb , Sb , Se and Zn . Among the trace elements with known biological function (Figure 6) Co showed a negative bal

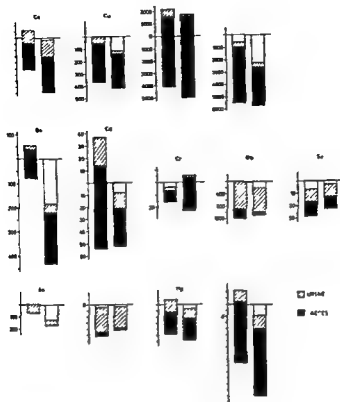


Figure 6 Trace element balances before and during treatment with oral phosphate and vitamin D_3 (for key see legend to Figure 4)

ance before and a positive balance during treatment. The balances of Cu and Zn were somewhat more positive after treatment than before. On the other hand the Fe balance was negative before as well as after treatment.

Among the balances of trace elements with suspected biological function the Cr, Rb, and Se balances were not changed in any definite way by treatment. The Ba balance was very similar to the Ca balance (Figures 4 and 6). The Cd balance like the Br balance was negative before and positive after treatment.

Some trace elements without known biological function were also determined. Among these elements the balances of As, Hg, and Sb became positive during treatment while the Cs balance was unchanged by treatment.

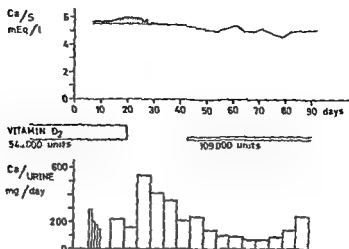


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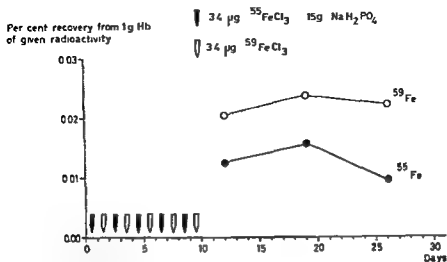


Figure 7 Double isotope study with regard to the effect of oral phosphate therapy on iron absorption. The Fe isotope given together with phosphate was incorporated more slowly into hemoglobin than the other isotope which was given without phosphate.

furniture. Although the muscle weakness was generalized it was obvious that the muscles of the shoulder and the pelvis were most severely affected. There were however no contractures.

A definite improvement in muscular strength was experienced by the patient after he had been in positive calcium and phosphorus balances for about one month. After 6-9 months of treatment the muscular strength could be considered as normal.

Electromyography was performed at three occasions before treatment was started and after six and nine months of treatment. In the first recording typical signs of myopathy were found. In the second there was an obvious improvement but still a slight overrepresentation of "thin" action potentials. The third recording after 11 months of treatment was considered to be normal.

RENAL FUNCTION

Before treatment was started serum creatinine was 0.75 mg per 100 ml and the glomerular filtration rate 140 ml/min (endogenous creatinine clearance). During the first 4 months of hospital treatment the serum creatinine was checked every week and was lower in all instances than 0.9 mg per cent. At the peak of hypercalcemia in August the

same year however (Figure 4) the serum creatinine was 1.2 mg per 100 ml and the filtration rate 92 ml/min. In April of 1967 renal function tests were as follows: serum creatinine 0.8 mg per cent, endogenous creatinine clearance 88 ml/min, inulin clearance 80 ml/min.

ALKALINE PHOSPHATASE

On admission the alkaline phosphatase was 19 Bessey-Lowry units (upper limit of normal = 25 units). It stayed only moderately elevated (6-10 units) until the calcium and phosphorus balances had been positive for about three weeks, at which time it rose to 16.5 units but fell again to a level of around 10 units. After the dose of 545 000 units of vitamin D was instituted in May, the alkaline phosphatase reached its highest value of 25 units and remained high, around 20 units, for two months. When the hypercalcaemia occurred in late August of 1966, the alkaline phosphatase had dropped to 6 units. Since then the value has been only moderately increased, 5 to 10 units.

ROENTGENOGRAPHIC FINDINGS

On admittance to the metabolic ward in January 1966, 35 Milkman fractures were present in the skeleton in most sites where such fractures have been described in osteomalacia (22). The collum femoris showed varus position bilaterally. The sternum was fractured at an angle of 90°. There was a pronounced thoracic deformity with marked gibbus of 90°, pigeon chest and cod fish vertebrae. There was also general and severe demineralization of the bone.

The first roentgenographic evidence of osteomalacia, such as patchy rarification of bones and Milkman fractures, were observed in 1959 after a six month history of low back pain. The roentgenological findings are summarized in Table 1.

After five months of treatment with vitamin D, calcium and phosphate, there was generally increased callus formation in the fractures and after seven months all of the Milkman fractures had healed completely. The low mineralization of the skeleton was still rather evident at this time, however.

MICORADIOGRAPHY OF THE BONE TISSUE

Biopsy of the bone was taken twice before effective therapy was started in January 1966 and after about half a year of treatment in October

Table 1

1959	<i>Febr</i>	Fractures of transverse processes of L ₁ , L ₂ , and L ₃ with moderate callus formation
Body height 176 cm		Fracture of the right 9th rib Rarefactions in the 9th, 10th, and 11th ribs on right side Normal X ray of the pelvis, hip joints, and upper parts of femors
	<i>Vol</i>	Additional destruction in the right 8th rib and the 8th and 9th ribs on the left side
	<i>Dec</i>	Generalized demineralization of the skeleton "Old fractures bilaterally in the upper parts of the tibiae and fibulae and in the fifth right metatarsal, all of them showing callus formation"
1960	<i>March</i>	Fracture without dislocation in the sacrum at the S ₄ level. Now also fractures in the right superior and inferior ramus of the pelvis, no dislocation
Body height 175 cm		
1963	<i>Febr</i>	<i>March</i> Demineralization of the skeleton more pronounced than in March 1960. Compression of the thoracic vertebrae which now have a wedge-like appearance. The fractures in the pelvic ring are healed relative to March 1960.
Body height 173 cm		Fracture of the right femoral neck with slight varus dislocation, visible callus. The old fractures in the tibiae and fibulae are still visible but largely healed.
	<i>May</i>	Additional fracture of the right 6th rib
1965	<i>Jan</i>	Marked deformity of the thorax with pigeon chest. The left lateral portion of the rib cage is pressed medially. The thoracic kyphosis has increased to almost 90° and there is a fracture of the sternum with an angulation of 90°. The fracture of the right femoral neck is still visible as in 1963, but the varus dislocation is more pronounced. There is now an almost identical type of fracture in the left femoral neck with a similar dislocation. Fracture with callus of the right tibia 10 cm below the knee joint. The "old" fractures in the tibiae and fibulae from 1959 are still visible.
Body height 163 cm		
1966	<i>Febr</i>	The whole skeleton is reexamined, and compared with Jan 1965. None of the fractures are healed. Recent multiple fractures in both scapulae. Extensive demineralization of the whole skeleton.
Body height 159.5 cm	<i>Jan</i>	
Body height 163 cm	<i>Sept</i>	Continued low mineralization of the skeleton. All fractures are healed.
1966	The specimens were taken from the lateral part of the iliac crest. Thus the material studied was composed mainly of cancellous bone. At the first biopsy the bone was very soft and elastic and was felt by the palpating finger as a piece of rubber. The bone specimen could be	

The possible gains from such an operation were considered small relative to the risk of impairment of respiratory function.

The loss of body height could not be attributed to the thoracic deformity alone. The fractures of the femoral necks resulting in a marked varus position in both hip joints caused shortening of the legs which could be estimated as 3 to 5 cm. The varus deformity also constitutes a risk of future osteoarthritis of the hip joints. Although this possibility could be considered an indication for corrective osteotomy of the femoral necks, the procedure has not been done thus far. Furthermore, it was considered unwise to immobilize the patient for another prolonged period by such operations and thus again delay his rehabilitation. It is possible, however, that orthopedic surgery will have to be performed at some time in the future if signs of arthrosis should appear in the hip joints.

DISCUSSION

The characteristic features of the present case: osteomalacia, hypophosphatemia, renal glucosuria in the absence of aminociduria and other tubular reabsorption defects fit well with the diagnosis of hypophosphatemic osteomalacia of Type II according to Dent's (7) classification with the important exception of the absence of a positive family history. This particular disturbance in renal tubular reabsorption must be extremely rare. A survey of the pertinent literature has thus far revealed only six cases (4, 7, 12) comparable with the actual case. In at least one of these cases no family history of metabolic bone disease was found. Furthermore, the type II tubular defect has occurred only in adults in contrast with the more common type I defect which obviously is far more common in children than in adults.

The present case was complicated by a bleeding ulcer that necessitated gastric resection four years after the onset of symptoms of metabolic bone disease. It is quite clear from the hospital records that the disease progressed rapidly after the gastric resection. Two main factors seem to have contributed to this, namely the lowering of the vitamin D₂ dose (for unknown reasons) from 50 000 to 5 000 units/day and the patient's dislike for dairy products which seems to have decreased his postoperative calcium intake to about 500 mg/day. The gastrectomy did not seem to cause any significant malabsorption since the daily fecal fat excretion was found to be within normal limits.

Compared to most reported cases of osteomalacia, the generalized skeletal destruction observed in this case including a very rapid thoracic

acic deformation in the course of three months was remarkable. Nevertheless the results of combined therapy with vitamin D₂, oral phosphate and calcium and orthopedic treatment was very gratifying, and resulted in a total rehabilitation of the patient in less than one year.

Most cases of hypophosphatemic osteomalacia have until now been successfully treated with large doses of vitamin D and frequently with calcium supplements. In many cases this can bring about not only healing of fractures but also normalization of serum phosphorus (23, 24). In this case 109 000 units of D did not normalize the serum phosphorus. In view of the risks of vitamin D intoxication by higher doses, as well as the protective effect of oral phosphate against hypercalcemia of all etiologies (13), it was decided to give oral phosphate in large amounts. Further support for the use of phosphate therapy was obtained from the papers by *Frame et al.* (9, 10) and *Rose* (12).

The course of the combined D₂ and phosphate treatment was fairly uncomplicated in spite of the fact that more than 500 000 units of vitamin D₂ were given for several months. Exceptions were two bouts of moderate hypercalcemia, one after 7 months of treatment with very large doses of vitamin D (Aug. Figure 4) and the second during the administration of a moderate vitamin dose in connection with an attempt to lower the phosphate dose (Dec. Figure 4). The second episode of hypercalcemia offers some support for the abovementioned hypothesis that phosphate is of value in minimizing the risk of vitamin D induced hypercalcemia. The question can be raised of whether in this case phosphate treatment alone could have produced the same good result: healing of fractures and rehabilitation of the patient without the risk of vitamin D intoxication. In fact two cases of the adult Fanconi syndrome are described where this has been tried evidently with good results (11). This type of therapy has been reported to be of little value in children with vitamin D resistant rickets, however (25). The mentioned therapy was not systematically investigated in the present study.

In spite of the fact that only two short periods of moderate hypercalcemia occurred during the treatment, a slight impairment of glomerular filtration was induced by the therapy. A plausible explanation for this undesirable effect is the well known vitamin D intoxication. It cannot be ruled out, however, that the phosphate treatment *per se* carries the risk of inducing renal injury. Some authors (5) have in fact reported unfavourable results with phosphate administration in renal tubular osteomalacia and they claim that it may cause renal in-

D₂ phosphate and calcium he was completely rehabilitated. By means of orthopedic extension treatment performed during the osteomalacic state some correction of the thoracic deformity was obtained which included a gain in body height of 5.5 cm. The balances for calcium, phosphorus and a number of trace elements were studied before and during treatment and are discussed. The experience from this case supports the view that oral phosphate has a place in the treatment of hypophosphatemic osteomalacia.

RESUME

Il est décrit un cas très grave d'ostéomalacie hypophosphatémique non héréditaire avec glucosurie rénale compliquée de résection gastrique chez un jeune homme de 27 ans. Les premiers symptômes se sont manifestés à l'âge de 18 ans. A 26 ans le malade était gravement invalide après une perte de hauteur du corps de 16.5 cm. Le développement d'une déformité thoracique et une myopathie proximale marquée. Après un an de traitement avec de fortes doses de vitamines D, de phosphate et de calcium il était entièrement remis. Au moyen d'un traitement par extension orthopédique pratiquée durant l'état ostéomalacique une certaine correction de la déformité thoracique a été obtenue avec une récupération de 5.5 cm de la hauteur du corps. Les métabolismes du calcium, du phosphore et d'un nombre d'autres éléments ont été étudiés avant et pendant le traitement et sont discutés. L'expérience acquise de ce cas souligne le point de vue que le phosphate oral a une place dans le traitement de l'ostéomalacie hypophosphatémique.

ZUSAMMENFASSUNG

Ein Fall von schwerer hypophosphatämischer nichterblicher Osteomalazie mit einer renalen Glykosurie kompliziert mit Ventrikelresektion bei einem 27-jährigen Mann wird beschrieben. Die ersten Symptome erschienen im Alter von 18 Jahren. Mit 26 Jahren war der Patient nach dem Verlust von 16.5 cm in Körperhöhe der Entwicklung einer thorakalen Deformität und einer ausgesprochenen proximalen Myopathie schwer invalidisiert. Nach einer einjährigen Behandlung mit hohen Dosen von Vitamin D, Phosphat und Calcium war er vollständig wiederhergestellt. Mittels orthopädischer Streckung, die während des osteomalazischen Zustandes ausgeführt wurde, konnte eine gewisse Korrektur der Thoraxdeformität erhalten und eine Zunahme der Kör-

perhohe um 5.5 cm gewonnen werden. Die Werte für Calcium, Phosphor und einer Anzahl von Spurelementen wurden vor und während der Behandlung untersucht und werden besprochen. Die Erfahrung aus diesem Falle unterstützt die Ansicht, dass orale Phosphatbehandlung einen Platz in der Behandlung von hypophosphatämischer Osteomalazie hat.

REFERENCES

- 1 Stowers J W & Dent C E. (1947) Studies on the mechanism of the Fanconi syndrome. *Quart J Med* 16 275
- 2 Wallis L A & Logle R L. (1957) Adult Fanconi syndrome. Review of eighteen cases. *Amer J Med* 23 13
- 3 Albright, F., Butler A W & Bloomberg E. (1937) Rickets resistant to vitamin D therapy. *Amer J Dis Child* 54 529
- 4 Mulkman L A. (1934) Multiple spontaneous idiopathic symmetrical fractures. *Amer J Roentgenol* 32 622
- 5 Williams T F, Winters R W & Burnett, C. H. (1960) Chapter 36 Familial hypophosphatemia and vitamin D resistant rickets. pp 1177-1221 in "The metabolic basis of inherited disease" McGraw Hill Co. Inc., New York.
- 6 Leaf A. (1960) Chapter 37 The syndrome of osteomalacia, renal glucosuria, aminoaciduria and hyperphosphaturia (The Fanconi syndrome) pp 1292-1343 in "The metabolic basis of inherited disease" McGraw Hill New York.
- 7 Dent C E. (1959) Rickets and osteomalacia from renal tubule defects. *J Bone Jt Surg* 34B 766
- 8 Fraser D, Jacob T, Yendt, E. R., Munn J D & Liu E. (1957) The induction of *in vivo* and *in vitro* calcification in bones of children suffering from vitamin D resistant rickets without recourse to large doses of vitamin D. *Amer J Dis Child* 93 84
- 9 Frame H & Smith R W Jr. (1958) Phosphate Diabetes. A case study of osteomalacia. *Amer J Med* 25 771
- 10 Frame H, Smith R W Jr & Wilson G. (1961) Acquired nonfamilial osteomalacia of vitamin D resistant type. *Henry Ford Hosp Med Bull* 9 548
- 11 Wilson D R & Yendt E R. (1963) Treatment of the adult Fanconi syndrome with oral phosphate supplements and alkali. *Amer J Med* 35 437
- 12 Rose G A. (1964) Role of phosphate treatment of renal tubular (hypophosphatemic) rickets and osteomalacias. *Brit med J* ii 857
- 13 Goldsmith R S & Ingbar S H. (1966) Inorganic phosphate treatment of hypocalcemia of diverse etiologies. *New Engl J Med* 274 1
- 14 Fiske C H & Subbarow Y. (1925) The colorimetric determination of phosphorus. *J Biol Chem* 66 345
- 15 Bessey O A., Lowry D H & Brock, W J. (1946) A method for the rapid determination of alkaline phosphatase with five cubic millimeters of serum. *J Biol Chem* 161 31
- 16 Jacobsson K. (1960) The determination of tartrate inhibited phosphatase in serum. *Scand J Clin Lab Invest* 12 367

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EPIDURAL ANAESTHESIA IN LOW BACK PAIN AND SCIATICA

By

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INTRODUCTION

Low back pain and its treatment form a complex problem. Conservative measures are manifold most of which have in common that the long term results are in general questionable. For temporary relief however alleviation of pain can be obtained in various ways of which e.g. epidural injections of either local anaesthesia corticosteroid preparations or saline separately or a combination of either compound have attracted some interest (Schgal Cardner 1960 Coomes 1961 Davidson Robin 1961 Mack 1964).

Caussade & Queste (1909) reviewed some cases in which they had used amylocaine hydrochloride with good results. A more thorough investigation was published by Evans (1930) who injected procaine and saline epidurally and claimed acceptable results in 22 of 40 patients with sciatica. Satisfactory effect was reported by Helman (1944) who had carried out 486 injections in 116 patients with sciatica 8 of these were cured 41 markedly improved 46 moderately improved and 17 only had slight improvement whereas 3 remained unchanged.

Gyrtax (1957) advocated epidural anaesthesia as the conservative method of choice for patients with low back pain. Those presenting neurological signs were treated in the same way.

Coomes (1961) has made a comparison of two groups of 20 outpatients with sciatica one of which was treated with epidural injections of 50 ml 0.5 per cent procaine the other with bedrest only. He found that pain relief was obtained in the epidural group within 11 days whereas the bedrest group needed 31 days for recovery.

Other agents than local anaesthesia have been used for epidural in

jections and in 1961 Davidson & Robin reported on 28 patients with sciatica who received large volumes (average 72 ml) of saline epidurally. They believed that nerve root pain was caused by the nerve root being compressed by hypertrophic tissue and adherent to it. They ascribed the successful results in their investigation to be due to the mechanical disruption of adhesions. In their investigation with saline only as injection fluid 4 were permanently cured and 16 obtained temporary relief. In 8 patients the injection had no effect. Of these 5 had a prolapsed disc and the return of symptoms after injection was explained by the nerve root being stretched over the prolapsed tissue. Temporary relief was however observed and this was thought to be due to a high hydrostatic pressure acting on the root. After absorption of the injected fluid the pathological situation was retained as before and thus pain returned.

Normally there is a negative pressure in the epidural space. According to Lindahl (1952) this disappears in association with sciatica. This disappearance was postulated as a symptom of an exudative inflammatory process. Corticosteroids injected epidurally have been claimed to yield satisfactory results (Sehgal, Gardner 1960; Mack 1964; Jacoby 1966; Hanse 1966).

In 1960 Brown reported on 20 patients in whom he injected first saline and following this 40 mg hydrocortisone tetracy butylacetate and 40 mg of prednisolone 21 phosphate either separately or in combination. 84 per cent improved with excellent and good results. No untoward effects were noted.

The technique by which the epidural injection is performed also attracts some interest. In 1962 Eriksson reported on long term epidural anaesthesia by a plastic catheter in the epidural space for 8 days. In these patients numbering 21 a mixture of local anaesthetic and hydrocortisone was injected. 16 patients improved within 5 days and could go back to work in about 11 days.

The rationale behind the effect of this treatment is obscure. It may be unwise to advance any theory of action but it may be worth mentioning the views of Sverdlow & Mark (1961) who think that the variation of the extent and duration of analgesia in epidural injections may depend on expanse of epidural space, size of escape routes, level of injection, volume of solution injected, speed and pressure of injection.

The object of this paper was to investigate the results of epidural anaesthesia in patients with low back pain and sciatica.

MATERIAL

This study comprises 49 patients (Table 1) all of whom received extradural injection treatment on 117 occasions

Table 1 Age and sex

Age	Male	Female	Total
20-30		1	1
31-40	5	5	10
41-50	13	6	19
51-60	7	6	13
61-70	4	1	5
Total	29	19	48

Of these 30 had not been operated at the time of the injection treatment whereas 18 who had previously been operated were treated for residual symptoms. The types of pain in both the non operated and operated groups were low back pain without irradiation and with sciatica. Tables 2 and 3.

Table 2 Diagnosis for injection treatment in non operated group

Sex	Low back pain				Total
	without irradiation		with sciatica		
	0 days- one week	3-7 months	2-3 months		
			right	left	
♂	1	7	4	6	18
♀	1	4	4	3	12
Total		11	8	9	30

Table 3 Diagnosis for injection treatment in operated group

Sex	Low back pain					Total
	without irradiation		with sciatica			
	0 days- one week	3-7 months	right	3-4 months	both	
				left		
♂	3	2	2	3	1	11
♀	2	2	1	1	1	7
Total	5	4	3	4	2	18

This investigation has only been concerned with registration of loss of pain in connection with epidural injections and no special reference has been made to neurological abnormalities or the straight leg raising test. From the results the patients in the different groups were classified as experiencing complete moderate or no relief of pain. Recordings were made immediately after injection by the anaesthetist and then on each consecutive day by the surgeon for at most one week. Checks were also made at the follow up clinic. Final registration was made one or two years after injection treatment.

METHOD

All patients were premedicated with 25 mg promethazine (Iergigan®). Prior to the injection 2 mg phenylephrine was given intramuscularly to prevent fall in blood pressure. The epidural anaesthesia was performed with the patient lying on his side. The level of injection was either L III, L IV or L V. The extradural space was identified by the loss of resistance technique (Sicard-Forestier). After a test dose of 2-3 ml of anaesthetic fluid had been given 2-3 min were allowed to elapse to be sure that no spinal anaesthesia accidentally ensued. The decided amount of the anaesthetic was then injected. As anaesthetic 1 per cent mepivacaine (Carbocaine®) was used in most of the cases. In 3 cases the 2 per cent solution was injected. In 3 patients 25 mg hydrocortisone was admixed to the anaesthetic. The volume of anaesthetic was around 20 ml. However in 7 instances less than 15 ml were given in 5 patients more than 30 ml were injected. 117 epidural blocks were given to 48 patients. 16 patients were given one block each. One patient received 9 blocks in periods for 8 months. The other patients were treated two or three times in periods up to two weeks. Single injection technique was used in all the cases.

RESULTS

The immediate effect of the epidural block was sensory loss and a sensation of heat in the lower part of the body. Motor paralysis was not always present which may be due to the concentration of the anaesthetic solution being weak.

Non Operated Group at Time of Injection

The pain sensation disappeared during the time of anaesthesia in all but five cases. When the anaesthesia receded pain returned in all patients. In 2 patients there was a gradual relief of pain to complete alleviation within one and two weeks respectively after the acute onset. At follow up two years later both patients were pain free. In one patient the alleviation was moderate after two months and has remained so two years later. In 22 patients the periodicity in the course of low back pain was in no way affected by the injection treatment (Table 4).

The 5 patients who did not experience any relief of pain during the

anaesthesia were later operated. In two a prolapsed disc was excised. These two patients recovered completely. In the remaining three no prolapse was found but scar tissue was observed to fix the nerve root to the posterior part of the intervertebral disc. After operation no relief of pain was recorded and a new series of epidural injections was instituted. Two recovered completely within 3 to 6 months respectively and are keeping well after 2 years. The patient who recovered in three months had received cortisone in combination with the anaesthetic. The third patient has not yet recovered two years after the final injection treatment.

Table 4 Results of injection treatment in non-operated group

Relief of pain remaining at 2 years follow up

Complete	Moderate	None
6	1	23

(four operated after injection)

(one operated after injection)

Operated Group

Eighteen patients received injection treatment because of pain despite previous surgical treatment at which a prolapsed disc was disclosed in nine although there was no prolapse in the remaining nine patients. If at surgery a prolapse was found it was removed. If no prolapse was seen the disc was not excised. No cases fused at this first intervention.

In the prolapsed disc group six have had no relief of pain but can carry out easier work. Of these two were reoperated for a recurrent prolapse but did not experience any relief of pain. Of the remaining three one has improved completely six months after injection treatment and two moderately after three and eight months respectively. In the no prolapse group one patient recovered moderately whereas the remaining eight have not improved (Table 5).

Table 5 Results of injection treatment in operated group

Finding at operation	Relief of pain			Total
	Complete	Moderate	None	
No prolapse		1	8	9
Prolapse	1	2	6	9
Total	1	3	14	18

COMPLICATIONS

Side effects were very few those recorded included headaches fall of blood pressure and intradural administration of the drug. In two patients technical difficulties arose which resulted in failure to obtain analgesia.

In three patients the anaesthetic was deposited intradurally. In one of these this was accompanied by a fall in blood pressure to about 60 mm Hg which was rapidly brought to normal. All three patients experienced headache lasting for 12-24 hours.

Despite prophylactic administration of mecloxedin in connection with the first few ml of anaesthetic a fall in blood pressure was registered in 12 patients to 100 mm Hg and below. On adequate treatment this was normalized in 10-15 min and no further untoward effects were noted.

COMMENT

The object of epidural injection treatment in lumbago is alleviation of pain. Judging from various reports however the postulated mechanism for this varies. Some believe in the local anaesthetic breaking the noxious circle of pain temporarily which may be all the patient needs to pass over into a state of more permanent relief (Eriksson 1962).

In an extensive experimental study in dogs on the dynamic factor in spinal cord compressions *Olsson* (1958) stated: "If now and then a small amount of disc tissue is pressed out through a rupture in the annulus fibrosus by active or passive movements of the spine the inflammatory reaction and subsequent irritation of the cord will persist together with clinical symptoms. Even very large protrusions may not cause symptoms if they are firm and do not continue to enlarge." Through its inflammatory effect a dynamic factor seems to be more responsible for the maintenance of symptoms than the actual compression. Any treatment which will eliminate the dynamic factor and thus reduce the inflammatory reaction seems to be of greater therapeutic value than direct surgical removal of the protrusion.

Corresponding views have previously been offered by *Lundahl & Rexed* (1960) based on a study on histologic changes in the nerve roots of cases operated for sciatica.

The influence of a local anaesthetic on an inflamed and irritated nerve root besides the pure neural block is still unknown. In normal peripheral nerves local anaesthetics slow down the intraneural micro-circulatory events and also cause a vasoconstriction of arterioles and

venules (Hansson 1966 Lundberg 1966) It is difficult to understand how an agent which causes a circulatory impairment under normal conditions can combat inflammation and bring about a longstanding relief of pain apart from the pure nerve block which follows the application of the local anaesthetic

In our hands epidural injections of local anaesthetics have not proved as successful as reported elsewhere and the rationale of it may be questioned

SUMMARY

The results of epidural injection of local anesthetics in cases of low back pain with and without irradiation have been reviewed

One group of 30 patients had not been operated prior to injection treatment The other group of 18 patients was treated for residual symptoms after previous surgery for a prolapsed disc in nine and in the remaining for a suspected but not operatively verified prolapsed disc

In all 117 injections were administered to the 48 patients

Results in non operated group Six experienced complete relief of pain Of these 4 were operated after injection treatment as this did not alleviate pain One had moderate relief Twenty three had no relief Of these one was operated after injection treatment

Results in operated group One experienced complete relief of pain three moderate and fourteen no relief

RÉSUMÉ

Les résultats d'injections épidurales d'anesthésiques locaux dans le cas de douleurs lombaires avec ou sans irradiation ont été réexaminés

Un groupe de 30 malades n'avait pas été opéré avant l'injection Un autre groupe de 18 malades avait été traité pour cause de symptômes restés à la suite d'interventions chirurgicales pour hernie discale dans 9 cas et pour les autres malades chez lesquels on soupçonnait une hernie discale qui ne serait toutefois pas vérifiée à l'opération

Tout 117 injections ont été administrées à ces 48 malades

Résultats pour le groupe des non-opérés Chez six les douleurs ont entièrement disparu Parmi ceux-ci 4 avaient été opérés après le traitement par les injections celui-ci n'avait pas supprimé la douleur Chez l'un il y avait eu un soulagement modéré 23 n'ont éprouvé aucun soulagement Parmi ceux-ci l'un a été opéré après le traitement par les injections

COMPLICATIONS

Side effects were very few, those recorded included headaches, fall of blood pressure and intradural administration of the drug. In two patients technical difficulties arose which resulted in failure to obtain analgesia.

In three patients the anaesthetic was deposited intradurally. In one of these this was accompanied by a fall in blood pressure to about 60 mm Hg which was rapidly brought to normal. All three patients experienced headache lasting for 12-24 hours.

Despite prophylactic administration of metoxedrin in connection with the first few ml of anaesthetic a fall in blood pressure was registered in 12 patients to 100 mm Hg and below. On adequate treatment this was normalized in 10-15 min and no further untoward effects were noted.

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- Hirsch C. & Nachemson A (1963) The reliability of lumbar disc surgery. *Clin Orth* 9^o 189-195
- Hirsch C. (1966) Low Back Pain Etiology and Pathogenesis. *Applied Therapeutics* 8 857-867
- Jacob B (1966) Behandling of discusprolapsus med ambulant epidural steroid injektion. *Nord Med* 76 1390-1391
- Lindahl O & Rexed B (1950) Histologic changes in spinal nerve roots of operated cases of sciatica. *Acta orthop scand* 20 215-225
- Lindahl O (1952) The pressure in the epidural space in operated cases of sciatica. *Acta orthop scand* 22 232-236
- Lundberg C Personal communication
- Mack E W (1964) Intrathecal steroid administration. *Rocky Mt Med J* 61 33-34
- Olsson S F (1958) The dynamic factor in spinal cord compression. A study on dogs with special reference to cervical disc protrusions. *J Neurosurg* 15 308-321
- Sehgal V D & Gardner W J (1960) Corticosteroids administered intradurally for relief of sciatica. *Cleveland Clin Quart* 27 195-201
- Swerdlow M & Brown J (1961) The effects of extradural injection of dilute local analgesics. *Brit J Anaesth* 33 642-647

Resultats dans le groupe des operes Un a été entièrement libéré de ses douleurs trois modérément et 14 n'ont éprouvé aucun soulagement

ZUSAMMENFASSUNG

Die Ergebnisse von epiduralen Injektionen in Fällen von Lumbago mit und ohne Ausstrahlung wurden durchgesehen

Eine Gruppe von 30 Patienten waren vor der Injektionsbehandlung nicht operiert worden Die andere Gruppe von 18 Patienten wurden wegen zurückbleibenden Symptomen nach vorhergehendem chirurgischen Eingriff wegen Diskusprolaps in neun und bei den übrigen wegen eines vermuteten aber bei der Operation nicht sichergestellten Diskusprolaps behandelt

Insgesamt wurden 117 Injektionen an die 48 Patienten verabreicht

Ergebnisse in der nichtoperierten Gruppe Sechs hatten ein vollständiges Verschwinden der Schmerzen Von diesen wurden 4 nach der Injektionsbehandlung operiert da diese die Schmerzen nicht erleichterte Ein Patient hatte eine massige Erleichterung Dreißig hatten keine Erleichterung Von diesen wurde einer nach der Injektionsbehandlung operiert

Ergebnisse in der operierten Gruppe Einer erfuhr vollständiges Verschwinden der Schmerzen drei eine massige Besserung und vierzehn wiesen keine Besserung auf

REFERENCES

- Bonica J J, Baelup P H, Anderson C, Hadfield H, Crepps W T, Monks B F (1957) Peridural Block: Analysis of 3637 cases and a review *Anesthesiology* 18 723-784
- Brown J H (1960) Pressure caudal anesthesia and back manipulation *Northw Med* 59 905-909
- Coomes F A (1961) A comparison between epidural anaesthesia and bed rest in sciatica *Brit med J* 1 20-24
- Davidsson J T & Robin G C (1961) Epidural injections in the lumbosacral syndrome *Brit J Anaesth* 33 595-598
- Friksson F (1963) Kontinuerlig epiduralanestesi vid lumbago (cihas) *Si Läkarskildn* 50 3721-3725
- Gross H (1965) Om terapi vid diskbräck i ländryggen *Documenta Geigy Folia rheumatologica* 2
- Hansen F (1966) Behandling af discusprolaps med epidural steroidinjektion hos indlagte patienter *Nord Med* 76 1391
- Hansson B Personal communication



Figure 1 Lateral view of the right os calcis with the vertical irregular sclerotic line

lar to the long axis of the calcaneus. The sclerotic line is located between the calcaneal tuberosity and the posterior articular surface for the talus.

DIAGNOSTIC PROBLEMS

Tenderness of the heel starting without trauma and with the typical x-ray findings may be reminiscent of early osteoid osteoma and osteosarcoma. Usually the osteosarcoma is very seldom localized to the calcis. If there is any doubt about the diagnosis surgical intervention is necessary.

TREATMENT

The main treatment of the stress fracture of the os calcis is to instruct the patient to avoid long walks, standing, jumping, running or stooping. A plaster cast can give comfort. The cast should be used for 4-6 weeks.

CASE HISTORY

A 43 year old nurse and was seen at the outpatient clinic at the Orthopaedic Hospital in Aarhus in August 1967 (case history no B 149757). For 6 weeks she had noticed slight swelling of the right ankle. No known trauma. For a week the right ankle and heel had been painful. Examination revealed a slight swelling of the lateral malleolar region, no haematoma and normal range of movement. X-rays showed a vertical fracture line between the calcaneal tuberosity and the posterior articular surface for the talus (Figure 1). A plaster cast was applied.

DISCUSSION

Earlier publications (1-4) give the impression that stress fractures of the metatarsal bones were the most common stress fractures. In 1967

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STRESS FRACTURE OF THE OS CALCIS

By

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Received 13 VII 67

There is no earlier report of stress fractures of the os calcis from Scandinavia. The incidence is proved to be very high in a series of 300 stress fractures among young soldiers in basic training in the army of the U.S.A. Darby (2) reported the incidence as 13.0 per cent. In an earlier report from the German Army Hospitals only four of 390 stress fractures were observed in the os calcis (4). In a series of 70 stress fractures Carlson & Weritz (1) found only one in the calcaneus. Larger series of stress fractures have been reported without respect to the total number of stress fractures in all sites. Winfield & Dennis (3) reported 42 calcaneal stress fractures in 31 patients. Judging from the literature the calcaneal fracture is worth remembering when the patient complains of calcaneodynia.

CLINIC

The histories are according to Darby (2) invariably similar. Pain in the involved heel within hours or days of prolonged exercise. The pain is usually not completely disabling as the patient often continues his work for weeks before seeing a doctor. There is no known trauma to the heel involved. The patient usually walks with a slight limp with the tender heel elevated from the ground. The heel is tender, often with some swelling also in the area of the malleolus. There is no discoloration.

X RAYS

Immediately after the onset of the symptoms the X ray shows no abnormality. After 2-3 weeks a repeated X ray examination will show definite changes (Figure 1) usually a linear sclerotic zone perpendicu-

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INFLUENCE OF GROWTH AND TRAUMA ON BONE MASS AND MINERAL TURNOVER IN RATS

By

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Received 2 VIII 67

Loss of bone mineral in fractured limbs of rats has been demonstrated by Bohr & Sorensen (1950) Bauer (1954) Bohr (1955) and others

This loss was not confined to the fractured bone but occurred also in the neighbouring bones. The loss of bone mineral was associated with an increased uptake of bone seeking radionuclides which was believed to reflect an increased bone formation rate that compensates for the resorption caused by the fracture. In preliminary experiments in this laboratory it was not possible to obtain any measurable change in the mineral content either of the femur following fracture of the tibia or in the tibia following fracture of the femur in rats. When comparing our data with those of other investigators it was found that the body weights of the animals in our experiments were much greater than those of the previous investigators so that our rats had reached a weight where growth was slow while previous investigators had used animals around 150 g when growth is rapid.

The purpose of the present study was to investigate the effect of growth on post traumatic osteopenia in the rat.

MATERIAL AND METHODS

One tibia (left or right at random) was fractured under ether anesthesia in twenty nine male Sprague Dawley rats of the Charles River strain. At the time of fracture the animals' ages ranged from 76 to 18 days (approximate weight range 10-300 g). Thirteen days following fracture they were injected subcutaneously with about two microcuries of Strontium-85 and twenty four hours later two weeks following fracture they were killed. The femora from the fractured and the control limbs were

cleaned of soft tissue and the fresh bone was weighed suspended from a fine copper wire in distilled water at 4 C mopped dry and re weighed in air. The volume was calculated as the difference between these two weights. The bones were then ashed at 600 C for forty eight hours and the ash weighed. Radioactivity was measured in a well scintillation detector to a precision of 1 per cent and expressed as a per cent of the injected dose.

RESULTS

The ash weight of the femora on the fractured side was less than that of the control femora (Figure 1). Moreover the specific ash weight (g ash/cc bone) was less on the fractured side (Figure 2). The volume of the femur on the fractured side was also less than that on the control side (Figure 3). When ash weight on the control and the fractured sides was plotted as a function of the bone volume there was no significant difference between control and fractured (Figure 4). Thus even though the femora on the fractured side had less total ash than the controls the ash content for any given volume was the same in both groups.

The total uptake of the isotope was less in the femora on the fractured side than in the femora of the control side (Figure 5) but the specific activity was higher on the fractured side (Figure 6). Specific activity (Figure 7) was found to be a negative function of specific ash weight (density) in the femora on the fractured side as well as the

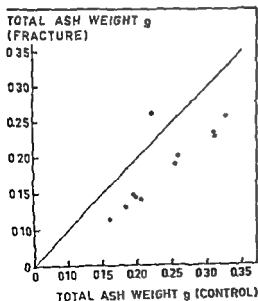


Figure 1 Total ash content of the femora on the fractured side is plotted against total ash content of the femora on the control side. All except one point fall below the horizontal line indicating that the ash content of the control femora is greater than that on the fractured side.

Figure 2 Specific ash weight in the fractured femur is plotted against specific ash weight in the control femur. All except one point fall below the oblique line indicating that the specific ash weight on the control side is greater than that on the fractured side.

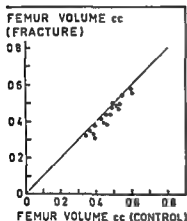
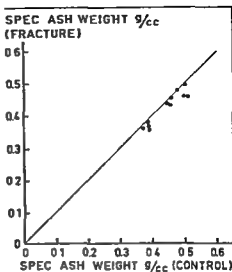
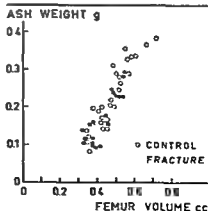


Figure 3 Femur volume on the fractured side is plotted against femur volume on the control side. All points fall below the oblique line indicating that femur volume was always greater on the control side.

Figure 4 Ash weight of the femora is plotted against femur volume for the control and the fractured sides. There is clearly no significant difference between the two sides.



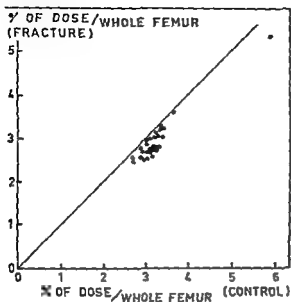


Figure 5 Total radioactivity in the femur of the fractured side \blacksquare plotted against total radioactivity on the control side. All points fall below the oblique line indicating that radioactive uptake is always greater in the control femora.

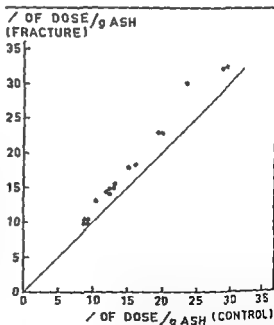


Figure 6 Specific activity in the fractured side was plotted against specific activity in the femora on the control side. In this case all the points fall above the oblique line indicating that the specific activity is always greater in the femora on the fractured side.

control side. Analysis of covariance revealed no significant difference between these two regressions so that for any given specific ash weight the specific activity was the same on the fractured side as on the control side. Actually the specific activity tended to be higher in the control.

This phenomenon may be explained by an exchange process which occurs more rapidly in the smaller and less dense bones

SUMMARY

The ash content the volume and the twenty four hour Strontium 85 uptake were measured in the femora of rats two weeks after fracture of one tibial shaft. The decreased mineral content of the femur ipsilateral to the fractured tibia was possible to explain by unilateral cessation of growth in the femur of the fractured limb. The ash content and twenty four hour isotope uptake were the same on the two sides when bone volume and density were held constant.

In this experiment specific activity twenty four hours following injection of Strontium 85 was best correlated with femur density and may not be regarded entirely as a parameter of bone formation rate.

RESUME

La teneur en cendres le volume et l'absorption pendant 24 heures de Strontium 85 ont été mesurés dans le fémur de rats deux semaines après une fracture d'un tibia. La diminution de la teneur en minéral du fémur du même côté que le tibia fracturé fournit peut être l'explication de la cessation unilatérale de la croissance du fémur dans le membre fracturé. La teneur en cendres et l'absorption d'isotope pendant 24 heures sont identiques des deux côtés lorsque le volume et la densité de l'os sont maintenus constants.

Dans cette expérience l'activité spécifique dans les 24 heures qui suivent l'injection de Strontium 85 est plutôt en relation avec la densité du fémur et ne doit pas être considérée entièrement comme le paramètre du taux de la formation osseuse.

ZUSAMMENFASSUNG

Der Aschengehalt, das Volumen und die vierundzwanzigstündige Strontium 85 Aufnahme wurden in Femuren von Ratten zwei Wochen nach Bruch eines Tibiaschaftes gemessen. Der herabgesetzte Mineralgehalt des Femurs ipsilateral zur gebrochenen Tibia konnte durch das einseitige Aufhören des Wachstums am Femur des gebrochenen Gliedes erklärt werden. Der Aschengehalt und die vierundzwanzigstündige Aufnahme von Isotopen waren die gleichen auf beiden Seiten, wenn Knochenvolumen und Dichtigkeit konstant gehalten wurden.

In diesem Versuch war spezifische Aktivität die 24 Stunden nach der Injektion von Strontium 85 auftrat am besten mit der Dichtigkeit des Femurs verbunden und sollte nicht vollständig als ein Massstab der Knochenbildungsgeschwindigkeit angesehen werden

REFERENCES

- Bauer G C H (1954) Rate of bone salt formation in a healing fracture determined in rats by means of radiocalcium *Acta orthop scand* 23 169
Bohr H (1955) Studies on fracture healing *J Bone Jt Surg* 37 A 377
Bohr H & Sørensen A H (1959) Study of fracture healing by means of radioactive tracers *J Bone Jt Surg* 32 A 567
Saville P D & Smith R E. (1966) Bone density breaking force and leg muscle mass as functions of body weight in bipedal rats *Amer J Physiol Anthropol* 25 30
Smith R E & Saville P D (1966) Bone breaking stress as a function of weight bearing in bipedal rats *Amer J Physiol Anthropol* 25 159

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ON THE DEVELOPMENT OF THE EPIPHYSIS OF THE FEMORAL HEAD FOLLOWING DISLOCATION OF THE HIP JOINT IN YOUNG RABBITS

By

H BOHR, K BAADSGAARD & P H SAGER

Received 6 vii 67

INTRODUCTION

In a previous paper (Bohr, Baadsgaard & Sager 1965) it was shown that dislocation of the hip joint in new born rabbits results in interruption of the vascular supply to the femoral head and ischemic necrosis of the epiphyseal bone. During revascularization it was demonstrated that vessels from the metaphyseal side perforated the epiphyseal plate with the formation of temporary bone bridges between the meta- and epiphysis. Upon the disappearance of these perforations within the first 4 weeks following the dislocation only little disturbance in the development of the epiphyseal bone was seen showing that sufficient blood supply was established.

The present investigation deals with the development and structural changes in the epiphyseal bone after dislocation of the hip joint in one week old rabbits studied by means of Tetracycline labelling and micro radiography.

MATERIAL AND TECHNIQUE

One week old rabbits had the right hip dislocated through gentle manipulation with pressure on the adducted femur. A slight click was felt at the dislocation which was confirmed on X ray photos. The animals moved freely and were able to support themselves on both legs shortly after the dislocation. In one experiment 7 rabbits

of two different litters had an injection of "Reverin" (Pyrrolidino-methyl tetra cyclin) 12.4 mg subcutaneously either on the day before dislocation of the hip or at different days after dislocation. In another experiment 6 animals from one litter had an injection of "Reverin" 17.5 mg subcutaneously the day before dislocation and some of the animals had a further one or two injections of "terramycin" (Oxy tetracycline) 17.5 mg subcutaneously on different days following the dislocation as seen in the table where the animals have been arranged according to age at sacrificing.

The animals were killed by an overdose of Nembutal and permanent dislocation of the hip was controlled on X ray photos of the intact animals. A careful dissection of the hip joints was performed with observations of the deformities and the development of the head and the neck of the femur as well as the acetabulum. Following removal of the femur X ray photos of the femoral head were made and after fixation and dehydration the proximal part of the femur was embedded in Methyl methacrylate. Sections were cut in the frontal plane with a rotating saw and after grinding under water to a thickness of 50 μ microradiography was performed using a Machlett X ray tube A.E.G. 88 supplied with a Wolfram anode generated at 12 kV and 10 mA. Exposures were made on Kodak Spectroscopic plates 649-0 at a film focus distance of 1a cm and with an exposure time of 10 min. The sections were then mounted on glass slides with "Depex" and the fluorescence in ultraviolet light observed using secondary Reichert filters OG1 and GG9. Two or three sections of each specimen were examined.

Table 1

Animal No	Label before disloc	Label after disloc	Killed after disloc	Semicircular "ring" from label before disloc
1	0	R. 1 day	2 days	
2	R. 1 day	0	3 days	+
3	R. 1 day	0	8 days	+
4	R. 1 day	0	7 days	-
5	0	R. 7 days	9 days	
6	R. 1 day	T. 9 days	10 days	+
7	R. 1 day	0	11 days	0
8	0	R. 9 days	13 days	
9	R. 1 day	T. 9 + R. 13 days	14 days	0
10	0	R. 13 days	15 days	
11	R. 1 day	T. R. + 17 days	18 days	0
12	R. 1 day	T. 18 + 22 days	24 days	0
13	R. 1 day	T. R. + 23 days	30 days	0

Labelling of animals with Reverin (R) and Terramycin (T)

The results are indicated as presence (+) or absence (0) of semicircular fluorescent "ring" corresponding to enchondral ossification before the dislocation of the hip joint.

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The present investigation deals with the development and structural changes in the epiphyseal bone after dislocation of the hip joint in one week old rabbits studied by means of Tetracycline labelling and micro-radiography.

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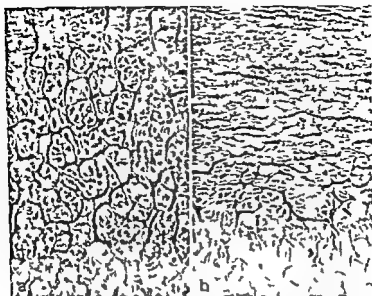


Figure 2 a Phase contrast photo of the articular cartilage of the right femoral head in animal No 3 showing increased layer of hypertrophic cartilage cells Magnification $\times 190$

Figure 2 b Phase contrast photo of the articular cartilage of the left femoral head (control side) in animal No 3 Magnification $\times 190$

out visible signs of persisting vessels. On radiographs the epiphyseal bone of the dislocated femoral head appeared distinctly diminished and showed some sclerosis during the first two weeks after dislocation but later regained normal size although with a somewhat deformed shape.

From fluorescence microscopy it can be seen that the uptake of ⁴⁵Ca in the epiphyseal bone the day before dislocation remains almost undisturbed in the femoral head during the following week. Thus the previous enchondral ossification below the articular cartilage persists in the right femoral head as a semicircular fluorescent ring while this ring disappears in the normal epiphysis of the left femoral head due to continued growth (Figures 1a and 1b). Despite the inhibition of ossification processes it can be seen that the articular cartilage of the right femoral head increases in thickness as compared with the control side. This is due to proliferation of the cartilage cells with formation of an increased layer of hypertrophic cells in the stage preceding enchondral ossification (Figures 2a and 2b).

At the beginning of the second week following dislocation revascular

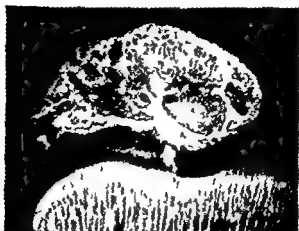


Figure 3. Fluorescent photo of the right femoral head in animal No. 9 labelled with Reverin the day before dislocation of the right hip and with Terramycin 9 and 13 days later. Sacrificed 14 days after dislocation. It is evident that the semicircular fluorescent ring from Reverin is broken and that enchondral ossification has been resumed. Magnification $\times 12$.

persistence of the fluorescent ring corresponding to the enchondral ossification during labelling the day before dislocation (Figure 1a). With revascularization ossification is resumed in conformity with the vascular contribution to osteogenesis (Trueta 1962), and bone formation takes place primarily by creeping apposition on the old trabeculae resulting in an increased density of the epiphyseal bone (Dobechko & Harris 1980, Hulth 1961 and Bohr & Larsen 1965). In the case of a young growing organism an image of the original epiphyseal bone is left inside the new developed bone giving the appearance on X-ray photos of a head within the head (Saller 1966). Such an image may be either positive or negative depending on whether appositional or resorption processes prevail. In the present investigation a positive "head in the head" can be observed during the time when the semicircular "ring" from the previous enchondral ossification remains (Figure 5a). With the disappearance of this ring a negative head in the head is seen due to the increased resorption (Figure 7a). During the following period new bone trabeculae are formed and the structure is normalized although some deformity of the femoral head may result. The observation that proliferation of the cells of the articular cartilage continues despite devascularization of the epiphyseal bone supports previous findings (Bohr, Baadsgaard & Sager 1965 and Sluts & Rolkenen 1966) and indicates that independent nutrition of the growing cartilage may take

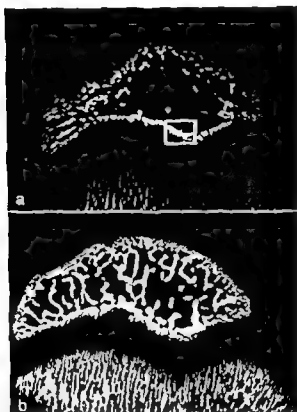


Figure 7 a Microradiograph of the right femoral head in animal No. 19 sacrificed 24 days after dislocation of the right hip. Osteoporosis and defects of the original epiphyseal bone can be seen. Magnification $\times 10$.

Figure 7 b Microradiograph of the left femoral head in animal No. 19. Magnification $\times 10$.

place probably from the synovial fluid (Ingelmark 1950, Ekholm 1951 and Brower Akashihi & Orlic 1962).

These results may be compared with the dystrophic changes in the femoral head which occur in relation to congenital dislocation of the hip joint in humans where the phenomenon of a "herd within the head" is often observed. From the evidence of the present investigation the appearance of a positive or a negative herd in the head may be explained owing to impairment of the vascular supply to the femoral head.



Figure 8. Fluorescent photo of the right femoral head in animal No. 12 corresponding to the enframed area on Figure 7. Small fragments of bone diffusely labelled with Reverin before dislocation of the right hip are left inside depositions of new bone between lines of Terramycin labelling 18 and 29 days after dislocation. Magnification $\times 50$.

SUMMARY

In one week old rabbits dislocation of the right hip joint with disruption of the vascular supply to the femoral head was performed and the development and structural changes of the epiphyseal bone were studied by means of Tetracycline labelling and microradiography. The results compared with the normal development on the control side show that the ossification processes stop leaving the previous enchondral ossification undisturbed during the following week although the proliferation of the cells in the articular cartilage proceeds. With revascularization 1-2 weeks after dislocation partly through vessels perforating the epiphyseal plate reconstruction of the epiphyseal bone takes place. Primarily an increased density of the epiphyseal bone is seen due to appositional bone formation. This is followed by osteoporosis with defects due to resorption of the original epiphyseal bone and with disappearance of the previous enchondral ossification line. The course of events is discussed in relation to the phenomenon of a "head within the head" seen following congenital dislocation in humans.

RESUME

Chez des lapins âgés d'une semaine il a été effectuée l'articulation droite de la hanche avec rupture vasculaire à la tête femorale afin d'étudier les changements structuraux de l'os épiphysaire sous l'influence de la tétracycline et de la microradiographie. Le développement normal du côté de contrôle de l'ossification normale laissant l'ossification inchangée durant la semaine suivante. Les résultats dans le cartilage articulaire ont montré une zone de nécrose 1-2 semaines après la dislocation en présence d'une perforation de la plaque épiphysaire. Une recalcification a commencé. Primordialement on observa une formation osseuse d'ostéoporose avec des défauts dus à la resorption originale et à la disparition de la ligne d'ossification. Il est discuté de l'évolution du processus d'ossification à l'intérieur de la tête observée après une dislocation chez les humains.

ZUSAMMENFASSUNG

Bei einer Woche alten Kaninchen wurde das rechte Hüftgelenk mit Unterbrechung der Gefäßversorgung der Femurköpfe durchgeführt und die Entwicklung und Struktur des Epiphysenknorpels mittels Tetracyclinmarkierung studiert. Die mit der normalen Entwicklung gleichenden Resultate zeigen, dass der Gelenkknorpel während der ersten Woche ungestört belassen wird, während sich im Gelenkknorpel fortsetzt. Mit 1-2 Wochen nach der Verrenkung beginnt der Epiphysenknorpel teilweise durch Gefäßstörungen zu degenerieren. Anfanglich wird eine erhöhte Resorption wegen übermäßiger Knochenbildung beobachtet. Osteoporose mit Defekten wegen Resorption des Epiphysenknorpels und unter Verschwinden der Ossifikationslinie. Der Verlust der Ossifikationslinie führt zu einer Zunahme auf die Erscheinung des Gelenkknorpels. Es wird diskutiert, dass die Entwicklung des Epiphysenknorpels nach einer Hüftverrenkung bei Menschen ähnlich ist.

REFERENCES

- Bobc hko W P & Harris W R (1960) Radiographic density of avascular bone *J Bone Jt Surg* 24 B 626-632
- Bohr H Baadsgaard H & Sager Ph (1965) The vascular supply to the femoral head following dislocation of the hip joint *Acta orthop scand* 34 264-278
- Bohr H & Larsen E H (1965) On necrosis of the femoral head after fracture of the neck of the femur *J Bone Jt Surg* 47 B 330-338
- Brower T D Akahoshi Y & Orho P (1962) The diffusion of dyes through articular cartilage in vivo *J Bone Jt Surg* 44 A 456-463
- Ekholm R (1951) Articular cartilage nutrition *Acta anat Suppl* 15
- Hulth A (1961) Necrosis of the head of the femur *Acta chir scand* 122 74-84
- Ingelmark H E. (1950) Nutritive supply and intritonal value of synovial fluid *Acta orthop scand* 20 144-155
- Salter R. B. (1966) Experimental and clinical aspects of Perthes disease *J Bone Jt Surg* 48 B 393-394
- Slatis P & Rokkanen P (1966) Regeneration of the femoral head after subcapital osteotomy *Acta orthop scand* 37 219-228
- Trueta J (1962) A theory of bone formation *Acta orthop scand* 32 190 198

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MEASUREMENT OF THE DEFORMITY IN SCOLIOSIS

By

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Received 31 v 67

Two major difficulties encountered in assessing the results of treatment for idiopathic scoliosis are firstly the impossibility of knowing the future spontaneous course when active measures are taken and secondly the uncertainty incurred in the measurement of the deformity. The former difficulty implies that some regression of the deformity must occur before it is possible to ascertain the effect of the treatment or else one half of the patients must remain untreated so as to provide a control group—an unattractive alternative.

If the regression is only of moderate degree more accurate methods for measuring the deformity are required than are at present available.

THE DEFORMITY IN SCOLIOSIS

The magnitude of the deformity in scoliosis is almost invariably assessed on the basis of the primary curve in a frontal view. The measurement of this curve on the film is usually performed by either *Cobb's* (1) or *Ferguson's* (4) method.

In the former the difference between the angle of the upper and lower surface of the upper and lower vertebrae respectively is measured (Figure 1) whereas *Ferguson* determines the angle between the mid-points of 3 vertebrae in which the upper and lowermost are defined by what is taken to be the primary curve and the third vertebra is one midway between them—or if there are two it will be one of them (Figure 2). Another method has been evolved by *Tidestrom* (8) in which the angular deviation of each vertebra is determined thus providing a general representation of the magnitude and extent of the scoliosis (Figure 3). The three methods are basically equivalent since they

REFERENCES

- Boehrkho W P & Harris W R (1960) Radiographic density of avascular bone
J Bone Jt Surg 24 B 626-632
- Bohr H, Baadsgaard H & Sager Ih (1965) The vascular supply to the femoral head following dislocation of the hip joint *Acta orthop scand* 35 264-278
- Bohr H & Larsen E H (1965) On necrosis of the femoral head after fracture of the neck of the femur *J Bone Jt Surg* 47 B 330-338
- Brower T B, Akahoshi Y & Orho P (1962) The diffusion of dyes through articular cartilage in vivo *J Bone Jt Surg* 44 A 456-463
- Fekholm R (1951) Articular cartilage nutrition *Acta anat Suppl* 15
- Hulth A (1961) Necrosis of the head of the femur *Acta chir scand* 122 74-84
- Ingelmark M E (1950) Nutritive supply and intritonal value of synovial fluid *Acta orthop scand* 20 144-155
- Salter H B (1966) Experimental and clinical aspects of Perthes disease *J Bone Jt Surg* 48 B 393-394
- Silast P & Rokkanen P (1966) Regeneration of the femoral head after subcapital osteotomy *Acta orthop scand* 37 219-228
- Trueta J (1967) A theory of bone formation *Acta orthop scand* 38 190-198

Figure 2 As in Figure 1 but the angles measured by Ferguson's method. Scoliosis angles then 30

Inclination of the upper surfaces of the vertebrae

Right 40 30 20 10 0 10 20 30 40 Left

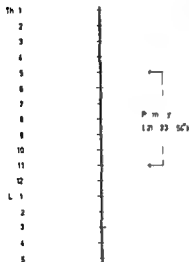


Figure 3 As in Figure 1 Registration of scoliosis angles by Tidestrom's method. The same scoliosis as in Figures 1 and 2

sidered but it is well known that small differences in setting the X-ray tube and in rotating the patient give different projections and hence different angles. Such changes in angle comply with the principles of solid geometry which however are fairly difficult to apply in practical work. It has been found by *Bergquist & Sevastikoglou* (7) that small changes in the direction of projection can result in changes in the scoliosis angle of up to 11 per cent.

The main source of error in determining the scoliosis angle is the lack of reproducibility of the projections from one occasion to another. The reason for this lies in the difficulty of defining the frontal plane and determining it clinically in cases of scoliosis, especially severe ones.

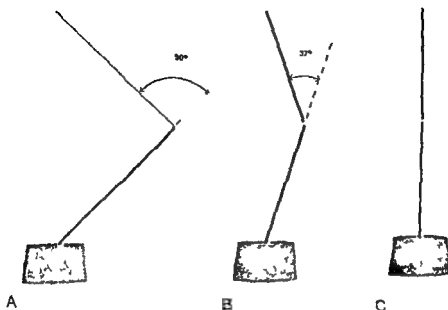


Figure 6 A steel wire bent through 90° (A) The scoliosis angle diminished as the wire is rotated (B) When it has been rotated through 90° (C) it is seen as a straight line

owing to the marked deformation of the abdomen. Because of the rotation that accompanies the scoliosis the maximum curvature does not lie in the frontal plane. The angle reproduced in the frontal film will therefore be too small by an amount that will depend on the discrepancy between the frontal plane and the plane containing the maximum angle.

As in the development of scoliosis the plane containing the maximum angle changes because of the rotation the error in the determination of the frontal plane will be supplemented by that incurred by the change in the plane of the maximum angle. After an operation to reduce this rotation it will be difficult if the difference is only moderate to ascertain by conventional methods whether or not the scoliosis angle has increased.

The determination of the *maximum scoliosis angle* and the deviation of its plane from the frontal plane is superior to conventional procedures for obtaining an impression of the deformations and if the methods of determination are reproducible it should be possible to make a comparison from one occasion to another.

It should be borne in mind that in the determination of the maximum

Figure 5 As in Figure 4 but the wire is inclined forwards so that the scoliosis angle is increased

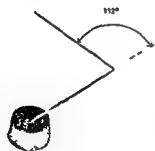
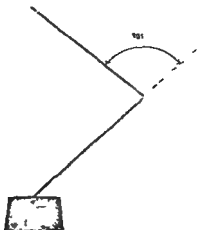


Figure 6 As in Figure 4 The wire is neither inclined nor rotated but the camera is placed above the level of the vertex of the angle the scoliosis angle is then increased

angle one is measuring a combination of pure scoliosis and kyphosis (or lordosis) This however is probably not a disadvantage

On the basis of a mechanical theory of the origin of scoliosis *Lindahl* has resected transverse processes and later on such processes and the posterior part of the ribs on the concave side of the scoliosis (5 6) The result of this was chiefly to reduce the rotation of the thorax rather than the scoliosis angle This angle was then measured by *Ferguson's* method and the usual radiologic technique



Figure 7 Idiopathic scoliosis as represented by the direct method. Right—The scoliosis is seen as a straight line. Left—Plane perpendicular to that of the right figure. The scoliosis angle then being projected to give its maximum value (33°).

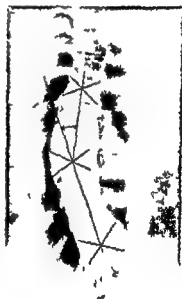


Figure 8 As in Figure 7 but with the scoliosis depicted on a conventional frontal film. The scoliosis angle is then 27° (—92 per cent).

To obtain a more accurate estimate of the way and the degree to which the scoliosis is affected by these measures a new radiologic technique has been evolved by which it is possible to measure the maximum scoliosis angle and the plane of this angle in relation to a vertical plane through the two iliac spines.

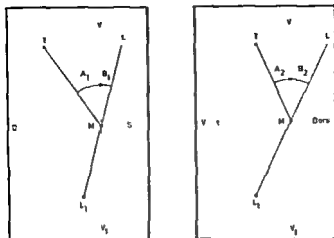


Figure 9 Diagram showing measurement of scoliosis angle by the mathematical method. Left—Film in the same plane as the iliac spines. Right—Film perpendicular to the former. To calculate the maximum angle the scoliosis angle $TM L$ is divided into the components A and B on each side of a vertical line (V_1).

METHOD

Two alternative methods were evolved.

The Direct Method

The patient is examined erect by fluoroscopy (oblique lateral projection) and rotated so that the scoliosis disappears and the spine is projected straight and vertical. The maximum scoliosis angle is then obtained with projection at right angles to the former and with the patient's position unchanged.

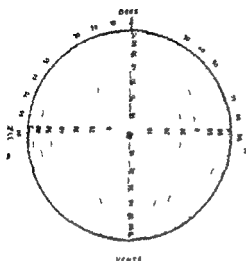
It is then also possible to measure directly the angle between this plane and a vertical plane containing the two spines. Accurate apparatus for measuring this angle is required.

The Mathematical Method

From the scoliosis angles measured on two perpendicular projections of the spine (arbitrary planes) it is possible by applying the principles of solid geometry to calculate (i) the maximum scoliosis angle and (ii) the angle between the plane containing the maximum angle and any of the planes of the projections. It is convenient to take one of the planes as that passing through the iliac spines. The solid geometry technique has been developed and applied to radiology by Edholm (2, 3). By means of a stereo instrument (designed by him and manufactured by Hifa St. Ekholm) it is quite a simple matter to determine angles without the need to resort to the otherwise inevitable mathematical calculations.

An advantage of this method is that the influence of any inclination of the spine to the vertical, or any adjustment above or below the maximum curvature is

Figure 10 Edholm's stereo instrument. Dorsal and Ventral are marked



automatically corrected for and there is no need to seek the position in which the scoliosis curve is projected as a straight line

MEASUREMENT OF ANGLES

A complete account of the theory underlying the measurement of angles in radiologic examinations is provided in Edholm's monograph (2). It will suffice here to outline the principles for the measurement of scoliosis angles. Figure 4 depicts a steel wire bent through a right angle. If the ends of the arms of the angle are held one vertically above the other the scoliosis angle will be seen to *decrease* as the object is rotated about an axis passing through the two ends (B). The maximum angle (90°) is obtained when the film is perpendicular to the plane containing the arms of the angle (A). On rotation through 90° from this position (C) the wire is seen as a straight line (the scoliosis angle is zero).

In Figure 5 the same wire is seen when no rotation is performed but the ends of the arms of the angle are inclined to the vertical. An inclination perpendicular to the direction of projection (to the sides) does not affect the size of the angle but an inclination in the direction of the central ray (forwards or backwards) results in a gradual increase in the angle.

Figure 6 shows the effect of altering the direction of the central ray above or below the actual apex of the angle. The rotation is the same throughout and there is no inclination in the vertical plane. This produces an *increase* in the scoliosis angle in both directions.

When the direct method is used it is necessary to eliminate these errors through controlled changes in position of the patient and the X ray tube but with the mathematical method the error in setting is corrected automatically in calculation of the angle.

PRACTICAL PROCEDURE

We use a focus to film distance of 140 cm and the patient is required to hold his arms above his head with the elbows bent. Vertical cassidles with grids are used in both projections.

When the direct method is used only one accurate setting is required as a rule any correction of the forward-backward inclination of the back being effected by fluoroscopy. In the projection that is perpendicular to the plane for which the scoliosis curve is reproduced as a straight line and *vertical* the maximum or true scoliosis angle is then obtained directly (Figure 7). In a conventional frontal film (Figure 8) the scoliosis angle will in this case be 7° smaller and it is difficult to reproduce this projection in repeated exposures. In the case of smaller changes of this frontal scoliosis angle one therefore never knows for certain whether the compared films are taken identically as regards rotation.

When the mathematical method is used the actual X ray examination is simpler to perform. Only 2 perpendicular projections are obtained one of which is taken parallel to the two iliac spines. The lower edge of both X ray films shall be horizontal. The central ray should pass through the middle vertebra in the scoliosis curvature. The only difficulty is then to calculate the required angles.

Figure 9 shows a scoliosis angle drawn with two perpendicular projections. The image on the left is in the same plane as the two spines (almost a frontal film) and that on the right is perpendicular to the former (practically a lateral film). In both projections the line 1-1, corresponds to the perpendicular through the middle vertebra (M).

To calculate the maximum scoliosis angle the scoliosis angles in the two projections must be divided into two one on each side of the vertical here designated A, A', B, and B'. These are oriented in different

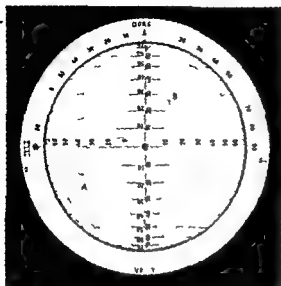


Figure 11 *Fidhols stereoinstrument* The coordinates for the maximum scoliosis angle have been entered with the guidance of the two values for A and B

directions A_1 to the right (Dx) and A ventrally and B_1 and B to the left (Sin) and dorsally respectively

If the angles are measured on the films in question the following values are obtained

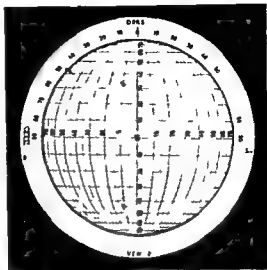
Component angles	Scoliosis angle in the respective projections
$A_1 = 30^\circ$ dx $A = 23^\circ$ ventral	$\left. \begin{array}{l} \\ \end{array} \right\} 58^\circ$ in the frontal film
$B_1 = 15^\circ$ sin $B = 27^\circ$ dorsal	
	$\left. \begin{array}{l} \\ \end{array} \right\} 42^\circ$ in the lateral film

From these values the required angles can then be obtained with *Fidhols stereoinstrument*

This instrument is shown in figure 10 and the 4 directions dx sin dorsal and ventral are drawn in on the instrument. In the following calculation the top transparent disk is provided for marking with a pencil and the middle disk is rotated 90° with respect to the bottom one.

Figure 11 shows how the angles are drawn in on the instrument in a coordinate system. A_1 and B_1 are set off on the meridians of the middle disk and A and B along the meridians of the bottom one. The value of A_1 which has the direction Dx is set off in the direction "Dx" on the instrument and A which has the direction "Ventral" downwards. The intersection of the coordinates gives the point A. In the same

Figure 12 Edholm's stereo instrument. The points A and B on the top disk have been rotated so as to lie on the same meridian of the bottom scale. The maximum scoliosis angle can then be read off on the vertical scale in the bottom disk. The rotation of the plane containing the maximum scoliosis angle is indicated by the arrow.



way the point B is entered. To obtain the maximum angles A and B the top disk on which the points are marked is rotated so that the points lie on the same meridian of the bottom scale (Figure 12).

On the vertical bottom scale it is then possible to read off these maximum angles (here 28° and 38°). The maximum scoliosis angle is thus 66° (28° + 38°). To reach this position it is necessary to rotate the top disk 47° counter clockwise and this angle (47°) corresponds to the plane of the maximum angle in relation to the sagittal plane (a plane perpendicular to that through the two iliac spines).

For a full account of the stereo instrument and the underlying mathematical theory the reader is referred to Edholm's paper. By means of the instructions given here it is possible to obtain the required angles without understanding the underlying theory.

In the cases in which the direct and mathematical methods were compared they showed close agreement and it would seem that either of them provides more accurate, complete and reproducible information on the deformation in scoliosis than the conventional procedures.

SUMMARY

The authors have evolved two X-ray methods by means of which it is possible to determine in different ways the maximum scoliosis angle and the angle between a frontal plane through the iliac spines and the plane containing the maximum angle. This technique enables a high

level of reproducibility to be obtained in the determination of the angles on different occasions. This is difficult with the usual technique where frontal films are not defined and therefore not reproducible.

RESUME

Les auteurs ont développé deux méthodes radiologiques au moyen desquelles il est possible de déterminer de différentes manières l'angle maximum de la scoliose et l'angle entre un plan frontal à travers les épinus iliaques et le plan contenant l'angle maximum. Cette technique permet dans la détermination des angles à différentes occasions d'arriver à un degré élevé de reproduction ce qui est difficile avec la technique ordinaire: les films frontaux n'étant pas définis et par conséquent impossibles à reproduire.

ZUSAMMENFASSUNG

Die Verfasser haben zwei Röntgenmethoden entwickelt mittels derer es möglich ist in verschiedener Weise den maximalen Skoliosewinkel und den Winkel zwischen einer Frontalebene und einer Ebene im maximalen Winkel zu bestimmen. Diese Technik ermöglicht es ein hohes Niveau von Reproduktionsfähigkeit bei der Bestimmung von Winkeln bei verschiedenen Gelegenheiten zu erhalten. Dies ist schwierig, mit der gewöhnlichen Technik bei der Frontalfilme nicht genau bestimmt und daher nicht reproduzierbar sind.

REFERENCES

1. Cobb J R (1948) *The American Acad of Orthop Surgeons* 5: 261
2. Edholm P (1966) Anatomic angles determined from two radiographic projections. *Acta radiol Diagnosis Suppl* 259
3. Edholm P (1967) Instrument for measuring angles from roentgenograms. *Acta radiol Diagnosis* 11: 156-166
4. Ferguson A H (1945) *Roentgen Diagnosis of the Extremities and Spine* Paul Hoeber Inc N Y
5. Lindahl O & Raeder E (1967) Mechanical Analysis of Forces Involved in Idiopathic scoliosis. *Acta orthop scand* 39: 27-38
6. Lindahl O (1963) The Rotation in Idiopathic Scoliosis. *Acta orthop scand* 33: 391-392
7. Sevastikoglou J A & Bergquist I (1967) Evaluation of the Reliability of Radiological Methods for Registration of Scoliosis. *Acta orthop scand* (In press)
8. Tidestrom I (1964) En metod för jämförbara registreringar av skolioser och kyfoser/lordoser. *Nord Med* 71: 159

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LUMBOSACRAL SYNOVIAL JOINTS IN FLEXION EXTENSION

By

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INTRODUCTION

Subluxation of lumbar synovial joints in narrowed discs has been reported by several investigators (Williams 1932 Johnson 1934 Lange 1936 Oppenheimer 1937 Hadley 1935 1936 1951 and 1961 Baumann 1957 and others). It has mostly been claimed to occur in lumbo sacral segments Harris & Macnab (1954) defined subluxations as follows

"A line was drawn on a lateral X ray through the inferior border of the vertebral body. If the top of the facet from the underlying vertebra was found a few millimeters above that level a subluxation was recognized (Figure 1)

Other authors (Hadley 1935 and 1961 Keller 1953 Baumann 1957) have identified subluxation as a contact between the upper edge of a S 1 facet and the L 5 pedicle in the intervertebral foramen (Figure 2). When these areas are forced against each other a dense contour is seen in lateral X rays. This is called impingement. In autopsy specimens with osteoarthritis in synovial joints and marked disc degeneration impingement has also been verified as a wider shaped upper facet area causing a dense radiographic appearance (Hadley 1935 and 1961 Baumann 1957).

The normal anatomy of lumbosacral joints has recently been studied in autopsy material (Lewin 1967). The most distal parts of L 5 pedicles are found in the intervertebral foramen lateral to the top of an S 1 facet. This means that the S 1 facet can move medially to the L 5 pedicle. Therefore in a lateral X ray the upper section of a S 1 facet will be projected upon the pedicle. High S 1 facets can occur as a normal variable.



Figure 1 Lumbosacral interspace. The height of the disc is normal. Macroscopically the disc is graded as degenerate. The synovial joints had no evidence of osteoarthritis. The picture is taken in flexion. The distal border of the L 5 vertebra is indicated. The top of the S 1 facet reaches the borderline of L 5.

Figure 2 The same specimen as in Figure 1 now in extension. The S 1 facet has a high position. Its upper border joins towards the medial deepening of the pedicle at the junction of the lamina isthmus.

Abnormal motion in the lumbar spine is often seen in synovial joints in extreme positions. It has been stated that it may indicate degenerative changes either in discs or joints. Impingement has been described as a possible cause of low back pain (Heller 1963 and 1964). Various manipulative procedures for correction of the positions of the facets have been discussed. It was therefore felt worth while to study the lumbosacral junction in flexion and extension in specimens with and without disc degeneration or osteoarthritis in synovial joints. With this in mind attempts were made to answer the following questions:

1. To what extent are the positions of S 1 facets in flexion and extension affected by degenerative changes in discs or joints at the lumbosacral junction?

2 Is the range of motion in lumbosacral synovial joints altered by degenerative changes?

3 Do radiographic studies of synovial joints indicative of disturbances in the pattern of motion in lumbosacral junctions justify conclusions about the pathomorphology?

MATERIAL AND METHODS

This study is based on 47 lumbar spines from routine autopsies. The subjects ages ranged from 20 to 80 years. The age and sex distribution is seen in Table 1.

Table 1 Age and sex

Age	20-45 years	45-80 years
	16	9
	10	7
	26	16
		25
		17
		42

The specimens were removed from the body of Th. XII to the sacrum and freed from musculature. The sacrum was fixed in a vice. Lateral roentgenograms were taken of the spines in flexion, extension and in normal resting position. The specimens were moved in a strict sagittal direction allowing the spines to assume an extreme position in either direction.

Disc degeneration was recorded and graded by gross anatomical evaluation after the discs had been cut horizontally (Frisberg, Hirsch and Schajowic). Discs with structural changes strictly confined to the nucleus pulposus and not attended by loss of disc height were accepted as normal. Degeneration was classified as annulus ruptures with or without loss of original fibre elements.

In one subgroup the size of the interspace was unaffected. In the other it was narrowed. The synovial joints were studied microscopically. Osteoarthritis was said to exist if the cartilage of the facets had decreased in thickness and additional bony changes such as osteophytes or subchondral alterations were seen.

In flexion the upper border of the S. 1 facet—as demonstrable in the lateral X-ray film—A line was drawn on L. 5 between the anterior and posterior distal edges of the vertebral body (Figure 1). In extension the projection of the upper point of the S. 1 facet relative to the distal border of the L. 5 pedicle was noted (Figure 2).

RESULTS

Flexion

In flexion (Table 2) the highest point of the S. 1 facet was found above the distal border of L. 5 in 17 cases, below in 13 and at the same level in 12. In two thirds of the spines where the level of the S. 1 facet

was high (10/17) no disc degeneration or osteoarthritis was present. More than one third of the specimens with low S 1 facets had narrowed interspaces (5/13 Table 3). Osteoarthritis was found only in those synovial joints where the top of the S 1 facets was higher than or the level of the line through the distal border of L 5. However, of all cases recorded as high or at the same level, less than one fourth had osteoarthritis (8/29 Table 2).

Table 2 Position of S 1 facets in flexion

Facet position	Disc and joint pathology				Total
	OO	DO	OA	DA	
Low	8	5	0	0	13
Level	5	4	1	2	12
High	10	2	1	4	17
Total	23	11	2	6	42

OO = normal disc no osteoarthritis

DO = disc degeneration no osteoarthritis

OA = normal disc osteoarthritis

DA = disc degeneration and osteoarthritis

Table 3 Position of S 1 facets in flexion of unaffected and of narrowed lumbosacral disc interspaces

Facet position	Disc interspace			Total
	Unaffected		Narrowed	
	O	D	D	
Low	8	0	5	13
Level	6	4	2	12
High	11	3	3	17
Total	25	7	10	42

O = normal disc

D = disc degeneration

Extension

In 22 of the 42 specimens when tested in extension the upper point of the S 1 facet was seen above the distal contour of the L 5 pedicle (Table 1). The discs and joints were normal in all of the 22. The same incidence of high S 1 facets was found when the disc space was nar-

rowed with or without synovial joint osteoarthritis (5/10 Table 5) In spines with normal lumbosacral discs and joints high facets were noticed in about half of them (11/23 Table 4)

Table 4 Position of S 1 facets in extension

Facet position	Disc and joint pathology				Total
	OO	DO	OA	DA	
Low	17	3	0	3	20
High	11	0	2	3	22
Total	23	11	2	6	42

Table 5 Position of S 1 facets in extension of unaffected and of narrowed lumbosacral disc interspaces

Facet position	Disc interspace			Total
	Unaffected		Narrowed	
	O	D	D	
Low	17	3	0	20
High	13	4	5	22
Total	23	7	10	40

Range of Motion

It is evident that the position of the S 1 facet varies both in normal and degenerate spines and does not indicate the morphology present. It was therefore felt that the range of movement of the synovial joint should be measured during maximum flexion and extension.

The figures presented in Table 6 were obtained by using the upper surface of the sacrum as a reference plane in the determination of the position of the L 5 facet. For all measurements the mean values \pm twice the standard deviation was between 4 and 8 mm.

When the estimated figures in a given case fell outside this range the movement in a particular joint was considered increased or decreased.

Increased facet motion was noticed in 3 cases with no disc degeneration or osteoarthritis and in one case with only osteoarthritis.

Limitation of motion occurred only in the osteoarthritic group (4/8). According to the hypothesis of equal distribution between groups dis-

was high (10/17) no disc degeneration or osteoarthritis was present. More than one third of the specimens with low S 1 facets had narrowed interspaces (5/13, Table 3). Osteoarthritis was found only in those synovial joints where the top of the S 1 facets was higher than or the level of the line through the distal border of I 5. However, of all cases recorded as high or at the same level, less than one fourth had osteoarthritis (8/29, Table 2).

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Table 3 Position of S 1 facets in flexion of unaffected and of narrowed lumbosacral disc interspaces

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In 22 of the 42 specimens when tested in extension the upper point of the S 1 facet was seen above the distal contour of the I 5 pedicle (Table 4). The discs and joints were normal in all of the 22. The same incidence of high S 1 facets was found when the disc space was nar-

were found between normal and degenerative spines which could be used to predict pathomorphological changes in discs or synovial joints.

One may question the tenability of these findings and conclusions. Differences in deformation between normal and degenerated discs under static loads have been shown to be significant but small (*Hirsch 1954, Nachemson 1963, Rolander 1966*). This in itself would mean that although one would expect some changes in the pattern of synovial facet positions they might not be measurable in lateral roentgenograms especially since differences in facet positions are commonly found in normal spines.

The range of motion in the lumbosacral synovial joint was measured. Disc degeneration did not affect the excursion of the L₅ facet relative to the sacrum. A decrease was noticed only in osteoarthritis which seems quite acceptable.

SUMMARY

Lateral X rays were taken of 42 lumbar spines removed at routine autopsy. The roentgenograms were taken with the spine in full flexion and extension and in the normal resting position. From these X rays the position of S₁ facets was determined. The fifth lumbar discs were cut horizontally for macroscopic evaluation of degenerative changes and the synovial joints of the lumbosacral segment were studied microscopically for osteoarthritis. It was found that the position of S₁ facets varied both in flexion and extension regardless of the presence of degenerative changes in discs and joints. The position of the facets did not justify any conclusion about pathomorphology in the lumbosacral segment. The range of joint motion was measured. Disc degeneration did not affect facet excursion. When the range of movement was decreased the synovial joints showed evidence of osteoarthritis.

RESUME

Des radiographies latérales de 42 colonnes lombaires prélevées au cours d'autopsies routinières ont été prises en flexion et extension complète ainsi qu'en position normale de repos. Sur la base de ces radiographies la position des facettes S₁ a été déterminée. Les disques de la cinquième vertèbre lombaire ont été coupés horizontalement afin de procéder à l'évaluation macroscopique des modifications dégénératives et les articulations synoviales de la région lombo-sacrée ont été étudiées au microscope pour détecter la présence d'ostéoartrite. On a découvert que

La position des facettes L1 varie en flexion et en extension sans rapports avec la présence de modifications dégénératives des disques et des articulations. La position des facettes ne justifie aucune conclusion concernant la pathomorphologie de la région lombaire. La mobilité de l'articulation a été mesurée et elle n'est nullement affectée par la dégénération du disque. En revanche en rapport avec une limitation du mouvement on a constaté la présence d'une ostéoarthrite dans les articulations synoviales.

ZUSAMMENFASSUNG

Laterale Röntgenaufnahmen von 42 Lendenwirbelsäulen, die von Autopsien erhalten worden waren, wurden in voller Beugung und Streckung sowie in normaler Ruhelage vorgenommen. Von diesen Röntgenbildern wurde die Lage der L1-Facetten bestimmt. Die fünften Lendenwirbeln wurden zur makroskopischen Bewertung von degenerativen Veränderungen horizontal geschnitten und die Synovialgelenke des lumbosakralen Segmentes wurden zum Nachweis von Osteoarthritis mikroskopisch studiert. Man findet, dass sich die Position der L1-Facetten bei Beugung und Streckung unabhängig von der Gegenwart degenerativer Veränderungen in Disken und Gelenken veränderte. Die Lage der Facetten erlaubt keinerlei Schlüsse hinsichtlich der Pathomorphologie im lumbosakralen Segment. Das Ausmaß der Gelenkbewegung wurde gemessen. Diskusdegeneration beeinflusste den Bewegungsausmaß der Facetten nicht. Wenn eine Bewegungseinschränkung vorkam, dann zeigten die Synovialgelenke Zeichen von Osteoarthritis.

REFERENCES

- Baumann J. (1957) Beiträge zur Kenntnis der Altersveränderungen der Lendenwirbelsäule beim Menschen unter besonderer Berücksichtigung des Bandscheiben und kleinen Wirbelgelenken. *Helv Acta Chir* 24: 9.
- Freiberg S. & Hirsch C. (1950) Anatomical and clinical studies on lumbar disc degeneration. *Acta orthop scand* 19: 72.
- Hadley L. A. (1933) Subluxation of the apophyseal articulations with disc impingement as a cause of back pain. *Amer J Roentgenol* 22: 709.
- Hadley L. A. (1936) Apophyseal subluxation. *J Bone Jt Surg* 15: 479.
- Hadley L. A. (1953) Intervertebral joint subluxation by impingement and foramen encroachment with nerve root changes. *Amer J Roentgenol* 63: 37.
- Hadley L. A. (1961) Anatomico-roentgenographic studies of the posterior spinal articulation. *Amer J Roentgenol* 86: 740.

- Harris R.J. & Macnab J (1954) Structural changes in the lumbar intervertebral discs *J Bone Jt Surg* 36B 304
- Hirsch C. & Schajowicz F (1959) Studies on structural changes in the lumbar annulus fibrosus *Acta orthop scand* 22 184
- Johnson R. (1934) Posterior luxations of the lumbosacral joint *J Bone Jt Surg* 16 867
- Keller G (1953) Die Bedeutung der Veränderungen an den kleinen Wirbelgelenken als Ursache des lokalen Ruckenschmerzes I Auswertung der klinisch-röntgenologischen Befunde *Z Orthop* 83 219
- Keller G (1953) II Auswertung der histologischen Befunde *Z Orthop* 83 517
- Keller G (1960) Wirbelgelenk und Ruckenschmerz Die Wirbelsäule in Forschung und Praxis 23 97 Hippokrates Verl. Stuttgart.
- Lange M (1936) Die Wirbelgelenke Enke Stuttgart
- Lewin T (1964) Osteoarthritis in lumbar synovial joints A morphologic study *Acta orthop scand* Suppl 73
- Lewin T Anatomical variations in lumbosacral synovial joints To be published
- Nachemson A (1963) The influence of spinal movements on the lumbar intradiscal pressure and on the tensile stresses in the annulus fibrosus *Acta orthop scand* 33 183
- Oppenheimer A (1937) Diseases affecting the intervertebral foramina *Radiology* 28 589
- Rolander S.D. (1966) Motion of the lumbar spine with special reference to the stabilizing effect of posterior fusion *Dissert*
- Williams P.C. (1939) Reduced lumbosacral joint space Its relation to sciatic irritation *J A.M.A.* 110 1677

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COMPARATIVE STUDY OF MYELOGRAPHIC FINDINGS IN ROOT SHEATHS AND OPERATIVE FINDINGS IN CASES OF SUSPECTED LUMBAR INTERVERTEBRAL DISC HERNIATION

By

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In 1931 *Arnell & Lindström* introduced the water soluble contrast medium Abrodil in myelography. However the new method did not acquire practical significance until about 15 years later when *Arnell* (1944, 1948) and *Lindblom* (1946) had worked out a technique by which they demonstrated the numerous advantages of the method and reduced its untoward side effects to an acceptable minimum.

In Scandinavia and later in several European centres myelography using water soluble contrast medium thereafter became the routine method for visualizing the lower part of the dural sac and the cauda equina. Therefore this form of myelography may now be assessed on the basis of a fairly comprehensive material (*Lemson* 1947, *Johansson* 1950, *Knutsson* 1951, *Andresen* 1953, *del Buono* 1957, *Schallingmark et al* 1958, *Kolstad & Solem* 1959, *Amundsen et al* 1963).

One of the main advantages of water soluble contrast medium above the previously used iodized oils is that it clearly visualizes the root sheaths thus facilitating a myelographic diagnosis of lateral disc herniations.

Arnell (1948) and *Lindblom* (1948) have studied the anatomical background of the myelographic picture of the root sheaths. They found the subarachnoid space of the root sheaths to vary widely in shape and extent from patient to patient and in each individual case there might be a certain asymmetry without amounting to morbid changes. According to the normal myelographic appearances of the root sheaths may

vary within wide limits and deficient of a root sheath need not necessarily mean a morbid condition in or around the nerve root concerned

Where a filling defect in the root sheath represents not only a congenital variation in development but a morbid condition there are various aetiological possibilities viz disc herniation spondylosis spondylolisthesis scar channels following previous operations sequelae of arachnoiditis tumours or sequelae left by fractures of the spine (Knutsson 1947 Arnell 1948 del Buono 1957 Walk 1958 Holstad & Solem 1959 Cronquist 1959)

In many cases a straight X ray film of the spine supplemented by myelographic examination will afford sufficient differential diagnostic certainty so that the nature and site of the disease may be deduced from a comparison of the radiological and clinical findings. But often a filling defect in a root sheath is the main or at times the only radiographic finding

In the by now comprehensive literature on myelography using water soluble contrast medium there does not seem to have been any analysis of the diagnostic significance of the deficient root sheath filling on the basis of a clinical material. Accordingly we felt that it would be of interest to investigate by comparing the myelographic root sheath appearances with the findings at operation in a group of patients with presumed disc herniations why the filling of the root sheath was deficient

MATERIAL

During the period January 1959 to April 1966 748 myelographies were done in the Orthopaedic Hospital Copenhagen on patients whose clinical symptoms and signs indicated disc herniations of one or more of the 3 caudal lumbar discs

The myelographies were carried out by the technique of Jensen (1947). The contrast medium used was 90 per cent Conturex (an Myel contrast Skiodan) (methyl iodide sodium)

The classification of the cases was based upon the reports of the radiologist and the surgeon in the case sheets

As far as the myelographic appearances of the root sheath are concerned a distinction will be made between 2 forms of filling defect viz faint filling and shortening. The assessment of the intensity of the contrast as well as of the length of the root sheath was based upon comparison with the symmetrical root sheath. Where a faintly filled root sheath was also shortened the case was assigned to the shortened group

Analyses of the 748 myelographies disclosed 229 cases in which a filling defect in a root sheath had been described and in which the nerve root concerned had been injected at subsequent operation. These 229 cases make up the present material

From the Orthopaedic Hospital Copenhagen Dept 1 and 2 (Heads A Bertelsen and HJ Larsen) and Dept of Radiology (Head M Schallimtzek)

COMPARATIVE STUDY OF MYELOGRAPHIC FILLING DEFECTS IN ROOT SHEATHS AND OPERATIVE FINDINGS IN CASES OF SUSPECTED LUMBAR INTERVERTEBRAL DISC HERNIATION

By

A. SKOU ANDERSEN & OTTO SØFFEREN

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In 1931 *Arnell & Lidstrom* introduced the water soluble contrast medium Abrodil in myelography. However the new method did not require practical significance until about 15 years later when *Arnell* (1944, 1948) and *Lindblom* (1946) had worked out a technique by which they demonstrated the numerous advantages of the method and reduced its untoward side effects to an acceptable minimum.

In Scandinavia and later in several European centres myelography using water soluble contrast medium thereafter became the routine method for visualizing the lower part of the dural sac and the cauda equina. Therefore this form of myelography may now be assessed on the basis of a fairly comprehensive material (*Leivson* 1947, *Johanson* 1950, *Knutsson* 1951, *Andresen* 1951, *del Buono* 1957, *Schallimtzek* 1959, *Kolstad & Solem* 1959, *Amundsen et al* 1963).

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Arnell (1948) and *Lindblom* (1948) have studied the anatomical background of the myelographic picture of the root sheaths. They found the subarachnoid space of the root sheaths to vary widely in shape and extent from patient to patient and in each individual case there might be a certain asymmetry without amounting to morbid changes. Accordingly the normal myelographic appearances of the root sheaths may

Thus in the present material a faint filling of a root sheath was a fairly uncertain sign of disc herniation.

Where the myelographic showed only a shortened root sheath (group B) 71.4 per cent of the operations revealed disc herniation in the site while 11.4 per cent of the cases exhibited other morbid conditions as a cause of the myelographic abnormality. In the remaining 17.2 per cent operation showed a normal looking and free root.

Thus a shortened root sheath was a fairly certain sign of herniation of a disc in relation to the nerve root.

Groups C and D represent cases in which the myelography showed not only deficient filling of the root sheath but also an abnormal shape of the contrast column. The operative findings therefore bore little relation to the deficient filling and are thus in this context of minor interest. However the groups are of some value as a basis for comparison with groups A and B.

Where the myelographic finding was not merely a deficient filling of the root sheath but also thinning of or impression into the contrast column (groups C and D) about 86 per cent of the cases showed disc herniation in relation to the root concerned while about 10 per cent exhibited other abnormalities to explain the myelographic findings. In the remaining 4 per cent the operation revealed a normal and free root.

As might be expected the more pronounced myelographic changes in groups C and D were relatively often signs of disc herniation and in these groups the anatomical findings around the root were seldom normal.

As is apparent from Table 1 170 cases (74 per cent) showed a disc herniation in relation to the deficiently filled root sheath. In 50 (29 per cent) of these cases the root was according to the operative report extended over the herniation and in 47 cases (28 per cent) squeezed. In 26 cases (15 per cent) the root was adherent while in 17 (10 per cent) it was flattened or narrowed and in 7 (4 per cent) showed diffuse or spindle shaped thickening. In 46 cases (27 per cent) the report gave no details concerning the root.

Another thing which appears from Table 1 is that in 33 cases (14.1 per cent) operative revealed no disc herniation but other abnormalities in explanation of the deficient root sheath filling. The operative findings in these 33 cases are listed in Table 2.

Table 2 shows that apart from disc herniations the most common cause of deficient root sheath filling was periradicular scar tissue left

Cases in which the filling defect was doubtful or in which it might have been due to technical reasons were excluded.

All the patients had undergone operation because of a suspicion of disc herniation and in all the myelogram and the clinical findings were in agreement in so far as the surgeons found in all cases indication for laminectomy or hemilaminectomy in order to inspect the root corresponding to the deficiently filled root sheath. In other words the clinical symptoms in all the cases might be imagined to be due wholly or partially to an affection of the root in question.

RESULTS

In Table 1 the myelographic and operative findings in 229 cases of filling defects are compared.

Groups A and B represent cases in which a filling defect of the root sheath was the only abnormal myelographic finding in relation to the disc concerned.

Table 1 Operative findings in 229 cases with defective root sheaths on the myelogram

Myelographs	Operative findings corresponding to the abnormal root sheath on the myelogram			Total
	Posterior herniation of the intervertebral disc	No posterior disc herniation but other abnormalities	No posterior disc herniation Nerve root free and normal	
Group A	32 (51.6%)	17 (27.8%)	14 (22.6%)	63 (100%)
Group B	20 (71.4%)	4 (14.3%)	6 (21.3%)	35 (100%)
Group C	11 (85.7%)	4 (30.8%)	5 (39.2%)	20 (100%)
Group D	59 (85.5%)	9 (13.6%)	1 (1.5%)	69 (100%)
Total	170 (74.2%)	33 (14.4%)	26 (11.4%)	229 (100%)

On the basis of the myelograms the cases are classified into the following 4 groups:

- A. Faint contrast filling of the root sheath. Normal contrast column.
- B. Shortened root sheath. Normal contrast column.
- C. Faint contrast filling of the root sheath. Impression into the contrast column.
- D. Shortened root sheath. Impression into the contrast column.

It is apparent from the table that where the only myelographic finding was a fairly faint filling of a root sheath (group A) only 51.6 per cent proved to have a disc herniation in relation to this root while 27.8 per cent showed other abnormalities in explanation of the myelographic findings. In the remaining 22.6 per cent the operations revealed a normal and free root.

and in 2 cases where the ligamentum flavum was greatly thickened an extremely cramped space in the root canal afforded an adequate explanation of the myelographic findings.

Lastly it will be seen from Table 2 that in one case operation revealed a root cyst and in another case diffuse thickening of the root. In the latter case the root sheath was divided; it showed considerable thickening and adhesions to the nerve fibres but these changes are unexplained.

Among the total material of 299 cases 26 (11.4 per cent) showed an apparently normal and free nerve root (cf. Table 1). It cannot be decided whether the myelographic appearances represented a non morbid asymmetry in the development of the root sheath or whether there was a question of a morbid phenomenon. But it may be mentioned that in 12 of the 26 cases there was herniation of a disc proximally to the deficiently filled root sheath. When considering the oblique course of the nerve roots it may be imagined that in some of these 12 cases the myelographic appearances were due to an influence by the named herniation upon the root in its proximal course.

DISCUSSION AND CONCLUSION

The present study did not include any assessment of the diagnostic accuracy obtained by the myelographic investigation as a whole. It turned exclusively at elucidating the cause of a single component in the myelographic picture viz. the deficiently filled root sheath.

Now a deficient filling of a root sheath is not infrequently the only myelographic evidence of disc herniation so that assessment of this very finding may decide whether or not surgery is carried out.

As might be expected on the basis of the studies of *Arnell* (1948) and *Lindblom* (1948) we found in the present material too that with a view to disc herniation the deficient filling of a root sheath was not a particularly specific sign.

The diagnostic uncertainty manifests itself especially in cases where funnel filling without shortening of the root sheath was the only myelographic finding. In this connection it is remarkable that disc herniation was found in only 52 per cent of the cases while 26 per cent exhibited other periradicular abnormalities.

In assessing these findings however it must be taken into consideration that in all cases the clinical symptoms might be imagined to be due wholly or partially to an affection of the root concerned. On this background the frequency of disc herniation is hardly above that which

would be expected if the operation had been done on the basis of clinical findings alone. Accordingly, the relatively faintly filled root sheath is a fairly certain sign of disc herniation which does little to support the clinical diagnosis.

Where a shortened root sheath was the only myelographic finding, operation showed in 71 per cent herniation in relation to the root and in only 11 per cent other abnormalities.

The shortened root sheath then is a relatively specific sign which gives good support to the clinical diagnosis of herniation.

In respect to the aetiology of root lesions not due to disc herniations, the findings in the present material were in keeping with those of previous clinical studies (Table 2). For instance, *Knutsson* (1947), *Cronqvist* (1959) and *del Buono & Luchs* (1959) found that frequently sequelae of herniation surgery manifest themselves myelographically as deficient filling of the root sheath, while *Andresen* (1953) found periradicular adhesions as an explanation of this myelographic appearance. It is known also that spondylolisthesis, osteophytes or a thickened ligamentum flavum may influence the filling of the root sheaths (*Irnell* 1948, *Johansen* 1950, *Cronqvist* 1959, *Lassbender & Stössel* 1960).

SUMMARY

In 229 cases showing deficient root sheath filling in (contrast medium) myelography, the myelographic and operative root findings were compared. In all cases the operation was done because of a suspicion of disc herniation.

When a faintly filled root sheath was the only myelographic abnormality, 51 per cent of the patients showed herniation in relation to the root concerned (Table 1, group A).

When a shortened root sheath was the only myelographic abnormality, 71.4 per cent of the patients showed herniation in relation to the root (Table 1, group B).

Where deficient filling of a root sheath occurred together with an abnormal contrast column, 86 per cent of the cases had disc herniation in relation to the root (Table 1, groups C and D).

The operative findings in 33 cases with root lesions unrelated to disc herniation are listed in Table 2.

It is concluded that a faint filling of a root sheath can only to some extent support a clinical diagnosis of disc herniation, while a shortened root sheath is a relatively specific sign of disc herniation.

RESUME

Dans 299 cas examinés à la myélographie Conturex (methiodole sodium) qui montraient un remplissage déficient d'une gaine de racine rachidienne les trouvailles myélographiques et opératoires ont été comparées. Dans tous les cas l'opération a été pratiquée parce qu'on suspectait une hernie discale.

Lorsque la gaine d'une racine rachidienne était faiblement remplie 51 1/2 pour cent des malades présentant cette anomalie avaient une hernie en relation avec la racine impliquée (Tableau 1 groupe A).

Lorsque le raccourcissement de remplissage d'une gaine de racine rachidienne était la seule anomalie 71 1/4 pour cent des malades avaient une hernie discale en relation avec cette racine (Tableau 1 groupe B).

Lorsqu'une gaine de racine defectueusement remplie a été observée en même temps qu'un contraste anormal dans la colonne 86 pour cent des malades avaient une hernie discale en relation avec cette racine (Tableau 1 groupes C et D).

Les trouvailles opératoires dans 33 cas de lésion de racines rachidiennes n'avaient aucun rapport avec une hernie discale sont rapportées sur le Tableau 2.

Il est conclu qu'un faible remplissage d'une gaine de racine rachidienne ne peut appuyer qu'à un certain degré le diagnostic clinique d'une hernie discale alors qu'un raccourcissement de la gaine d'une racine rachidienne est un signe spécifique de la hernie discale.

ZUSAMMENFASSUNG

In 299 Fällen die mangelhafte Wurzelscheidenfüllung bei der Conturex (Methiodole Natrium) Myelographie zeigten wurden die myelographischen und operativen Wurzelbefunde verglichen. In allen Fällen wurde die Operation wegen des Verdachtes einer Diskushernie vorgenommen.

Wenn eine schwach gefüllte Wurzelscheide die einzige myelographische Anomalie war zeigten 51 1/2 Prozent der Patienten Hernienbildung im Verhältnis zu der betroffenen Wurzel (Tafel I Gruppe A).

Wenn eine verkürzte Wurzelscheide die einzige myelographische Anomalie war zeigten 71 1/4 Prozent der Patienten Hernienbildung, im Verhältnis zur Wurzel (Tafel I Gruppe B).

Wo mangelhafte Füllung, zusammen mit einer abnormalen Kontrastsaule auftraten hatten 86 Prozent der Fälle eine Diskushernie im Beziehung zur Wurzel (Tafel I Gruppen C und D).

Die operativen Befunde in 33 Fällen mit Wurzelschädigungen ohne Beziehung zu einer Diskushernie sind in der Tafel 2 angeführt.

Man schliesst, dass eine schwache Füllung einer Wurzelscheide nur bis zu einem gewissen Grade die klinische Diagnose einer Diskushernie unterstützen kann, während eine verkürzte Wurzelscheide ein verhältnismässig spezifisches Zeichen einer Diskushernie ist.

REFERENCES

- Amundsen I., Helsing P. & Kristiansen K. (1963) Evaluation of lumbar radiography ("myelography") with water soluble contrast media. *Acta radiol* 2: 659.
- Andresen I. (1953) Et materiale af abrodilmvelografier. *Nord Med* 50: 1401.
- Arnell S. & Lidström I. (1931) Myelography with Skiodan (Abrodil). *Acta radiol* 12: 197.
- Arnell S. (1944) Weitere Erfahrungen über myelographie mit Abrodil. *Acta radiol* 25: 408.
- Arnell S. (1949) Myelography with water soluble contrast with special regard to the normal picture. *Acta radiol* Suppl. 45.
- Cronqvist S. (1959) The postoperative myelogram. *Acta radiol* 50: 45.
- Del Buono M. S. (1957) Die lumbale Myelographie zur Diagnose der Diskushernie. *Fortschr Geb Röntgenstr* 87: 334.
- Del Buono M. S. & Fuchs W. L. (1959) La myelographie lumbaire post opératoire. *Ann Radiol* 11: 837.
- Fassbender C. W. & Kissel H. G. (1960) Die Bedeutung der Übersichtsaufnahme (Lateral Aufnahme) der Lendenwirbelsäule und der Abrodil Myelographie beim lumbalen Bandscheibenvorfall. *Neurochir* 3: 79.
- Friberg S. & Hult L. (1951) Comparative study of abrodil myelogram and operative findings in low back pain and spondylitis. *Acta orthop scand* 20: 303.
- Johansen C. E. (1950) Results of myelographies with water soluble media. *Acta orthop scand* 99: 60.
- Knutsson F. (1941) The myelogram following operation for herniated disc. *Acta radiol* 32: 60.
- Knutsson F. (1951) Lumbar myelography with water soluble contrast in cases of disc prolapse. *Acta orthop scand* 20: 294.
- Kolstad E. & Slemme H. (1959) Myelografi med vannopløselig kontrastmiddel. *Nord Med* 61: 306.
- Leivson H. (1947) Abrodilmvelografi. *Lægekr Læg* 38: 545.
- Lindblom K. (1946) Lumbar myelography by abrodil. *Acta radiol* 27: 1.
- Lindblom K. (1949) The subarachnoid spaces of the root sheaths in the lumbar region. *Acta radiol* 30: 419.
- Schalmitzek M. (1953) Roentgenological examination of the function of the lumbar spine. Universitetsforlaget Aarhus.

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WEDGE OSTEOTOMY OF SPINE IN ANKYLOSING SPONDYLITIS

By

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Severe ankylosing spondylitis often leads to complete ankylosis of the spine sometimes with pronounced kyphosis. The kyphosis is due among other things to the patient sleeping with too many pillows under his head because of the nocturnal pain.

Extreme kyphosis causes thoracic and abdominal pain and what is more limitation of the distance the patient can see ahead of him. Sometimes the axis of vision is directed almost perpendicular to the ground. In such cases the patient cannot use busy thoroughfares.

Smith Petersen Larsson & Aufranc (1945) were the first to describe wedge osteotomy of the spine. Since then several large series have been published by Herbert of Aix le Boin and others. La Chapelle (1946) used a two stage procedure: first wedge osteotomy from behind through the spinous processes and arches and after an interval of some weeks chiselling through the vertebra or dividing the anterior longitudinal ligament from an anterior approach.

Herbert (1955) has performed 42 wedge osteotomies in various parts of the spine including 3 in the cervical region, 1 in the upper thoracic region, 9 in the lower thoracic region and the rest in the lumbar region. In 10 cases he used the two stage procedure. Complicating paraplegia occurred in 2 cases, in 2 of which it disappeared after decompression while in the third it persisted and the patient died.

Briggs, Keats & Schlesinger (1947), Law (1949) and Adams (1952) preferred immediate correction on the operating table as well as fusion. Kallio (1963) reported 1 case in which he performed a one stage operation with immediate correction and fixed the spinous process with a loop made of a long piece of skin.



Figure 1 A Case 1 Thoracic spine before operation The pseudarthrosis is located between Th VI and VII

Figure 1 B Case 1 Thoracic spine 3 weeks after osteotomy Observe how the pseudarthrosis has functioned as part of the wedge osteotomy



Figure 2 A Case 5 Lumbar spine before operation Observe the assumed pseudarthrosis just above the middle of the reproduction

Figure 2 B Case 5 Lumbar spine after osteotomy Observe how the osteotomy has been done The pseudarthrosis was not true but only apparent The disk was immovable Therefore the vertebrae was chiselled through from behind and the spine corrected

From 1950 to 1962 five patients were subjected to wedge osteotomy at Lund always because the patients were unable to look forward The patients also had other symptoms such as respiratory difficulties abdominal discomfort and pain but not sufficient to indicate operation Candidates for osteotomy must be selected very carefully for rehabilita

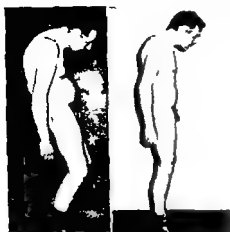


Figure 3 Case 1 before operation (left) and 10 months after osteotomy (right)

tion requires a long time. In other words the operation should be considered only when it has much to offer.

The 5 osteotomies were performed as one stage operations with a wedge osteotomy posteriorly and then gradual redressment in a plaster cast for 3 weeks.

What we found useful in the one stage operation was that some patients had a pseudarthrosis between two vertebral bodies of the otherwise ankylosed spine. Such pseudarthrosis may perhaps be due to a fracture of the bamboo spine.

In all of the cases such a pseudarthrosis could be observed and we performed the osteotomy at that level. We found however that the "pseudarthrosis" was not always true but only apparent. See Figures 2A and 2B.

The operation requires patience on the part of the surgeon. Two thirds of the circumference of the dural sac must be exposed. To judge the size of the wedge we used stainless steel plates of 15, 20, and 30. Dural injury could be avoided in 4 of the 5 cases. The escape of fluid in the 5th case was not troublesome and caused no secondary complication. Anaesthesia may be problematic. General anaesthesia is not satisfactory since the patient is prone during the operation and since the thoracic cage is completely rigid. Intubation is practically impossible. Local anaesthesia may be used but it places large demands on the patient. We have found extradural anaesthesia very satisfactory and it is probably the best method available for such patients. The case reports are given in Table 1.

It is clear from the Table that the postoperative period of immobili-

Table 1

Age sex year of operation	Interval between operations of disease and op (yr)	Level of osteotomy and anaes- thesia	Redresse- ment period after op (wk)	Immobili- zation plaster cradle (wk)	Plaster corset (mth)	Improve- ment in angle	Postop compl	Interval between op and review and results
1 43 yrs ♂ 1950	9	Th XI-XII local	6 weeks	1½	9 months	25	Spasmodic pain Slight lip cyanosis	11 yrs Very satisfied no disability Angle of vision decreased a few degrees
2 47 yrs ♂ 1951	27	L I-L II local	3 weeks	7	5 months	20	Slight abdominal discomfort	8 yrs Very satisfied no disability Angle of vision decreased a few degrees
3 43 yrs ♂ 1958	13	Th XI-XII local	3 weeks	12	6 months	30°	Slight decubitus over sacrum	7 yrs Very satisfied Felt very well first year Then arthritis of hips Disability pension
4 32 yrs ♂ 1959	13	L III-L IV extradural	3 weeks	11	5 months	20	See pseud arthrosis Recop with fusion 18 months later	3 yrs Satisfied Works after vocational train- ing Sedentary occupa- tion Angle of vision decreased a few degrees
5 42 yrs ♂ 1967	12	L I-I II extradural	3 weeks	12	7 months	24	Meteorism	2 yrs Very satisfied Works as a clerk No decrease of angle of vision

sation is long 7-15 weeks in a plaster cast including 3 weeks for redressement and then the use of a plaster corset for 5-9 months. Complications occurred in one patient (Case 4) who developed pseudarthrosis at the site of the osteotomy when he was recumbent the spine was relatively straight but when he stood up it flexed 20° and he was thus unable to look ahead. 1½ years after first surgery he was reoperated upon and fused with an iliac graft and bone chips. He is now able to do certain kinds of work. All of the 5 patients are satisfied with the result of the operation.

Patient No. 3 developed arthritis of the hip 2 years after the operation but nevertheless considered that the improvement of the axis of vision was extremely valuable. Patient No. 3 is the only one who cannot work and who has therefore been granted a disability pension.

SUMMARY

In patients with a bamboo spine extreme kyphosis and consequent downward direction of the axis of vision wedge osteotomy of the spine may be indicated. The operation places large demands on the surgeon's patience but is not hazardous. The rehabilitation period is long but all 5 patients operated upon in Lund between 1950 and 1962 are more than satisfied with the relief the operation has given.

RÉSUMÉ

Chez les malades ayant une colonne vertébrale en forme de bambou, extrême cyphose et par conséquent une inclinaison de l'axe de vision, une ostéotomie en coin de la colonne peut être indiquée. L'opération requiert beaucoup de patience de la part du chirurgien mais elle n'est pas hasardeuse. La période de traitement est longue mais tous les 5 malades opérés à Lund entre 1950 et 1962 ont été extrêmement satisfaits du soulagement que l'opération leur a apporté.

ZUSAMMENFASSUNG

Bei Patienten mit einer Bambuswirbelsäule extremer Kyphose und folgender Abwärtsrichtung der Sehachse kann Keilosteotomie der Wirbelsäule angezeigt sein. Die Operation erfordert grosse Geduld von seiten des Chirurgen ist aber nicht gefährlich. Die Wiederherstellungszeit ist lang aber alle 5 Patienten, die zwischen 1950 und 1962 in Lund operiert

wurden sind mehr als zufrieden mit der Erleichterung die ihnen die Operation gebracht hat

REFERENCES

- Adams J C (1952) *J Bone Jt Surg* 34B 226
 Briggs H Keats S & Schlesinger Ph P (1947) *J Bone J Surg* 29 1075
 La Chapelle E H (1946) *J Bone Jt Surg* 28 851-858
 Herbert J J (1955) *Memoire de L Académie de Chirurgie* Nos 4 et 5
 Hallio H E (1963) *Ann Chir Gynaec Fenn* 52 615
 Law A (1949) *Proc roy Soc Med* 594-597
 Smith Petersen M N Larsson C B & Aufranc O E. (1945) *J Bone Jt Surg* 27 1
 Wiberg G (1952) *Nord Med* 48 1530

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UNILATERAL JUVENILE MUSCULAR ATROPHY OF UPPER LIMBS

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In 1959 *Hirayama* and co workers (1) drew attention to a new clinical entity of juvenile muscular atrophy of unilateral upper limb based on their experience of 12 cases. In 1963 *Hirayama* and co workers (2) reported a more detailed study including laboratory tests of 11 of the 12 and of 9 new patients. Early onset localized muscular atrophy of one arm, the disease is progressive in the one arm for some years and then becomes stationary. This form of muscular atrophy is distinctly different from any other entities of muscular atrophy hitherto described. In 2 patients *Hirayama* and co workers (1, 2) found hyperactive deep reflexes of the leg on the affected side. This paper describes a typical case, the symptoms and the diagnostic problems.

CASE REPORT

A 23 year-old male undergraduate (engineer) was admitted to the out patient clinic at Orthopaedic Hospital in Aarhus on February 28, 1966. A few weeks before admission he had been found unfit for military service because of selective atrophy of the right upper arm.

The young student, who had never been in hospital before, now wanted to be examined.

His family history was noncontributory. During school age he had been healthy. 8 years ago he started to work as an electrician apprentice and already the first winter he noticed that he fumbled when using a small screw-driver and occasionally he unintentionally dropped the screw-driver—he was right handed. Occasionally he had been aware of a fine tremor of the fingers of the right hand, especially when he was working with small objects. When it was cold the right hand was stiff and felt cold. He had no pain or paraesthesia. Three years previously, when he started his education as an engineer, he was aware of a slight progressive weakness of the grip of his right hand and he felt some trouble in using a pencil for more than 2-4 hours.

without a rest. He had no pain in the neck or trouble with the left hand or his lower limbs. The past 2 years he had not noted any progression or changes on the affected side.

Two years ago he had an attack of dizziness after he had been working for 5 hours at the drawing table. He stayed in bed for a week and was bothered by some dizziness for 3 months followed by jerks of the head. He has not had any such attack since. No headache, no tinnitus or disturbances of vision. He cannot recall any spell of fever or the possibility of polio myelitis. He still uses the right hand more than the left.

Examination on February 28, 1966, revealed a well-nourished and healthy-looking young man with considerable atrophy of all intrinsic muscles of the right hand. The right thenar eminence was atrophic. There was decreased power of abduction of all the fingers. Some weakness of the flexor profundus to the IV and V finger together with weakness of the flexor pollicis longus and brevis. There was slight paresis of the extensor carpi ulnaris muscle. The other muscles of the right arm and shoulder girdle were normal.

There was a slight asymmetry of the face without changes of the mimic muscles or the sternocleidomastoid muscles.

Very pronounced fascicular twitchings were observed in the atrophied muscles, especially in the first interosseous muscle. Appreciation of light touch (wisp of cotton wood) and superficial pain (pinprick) was normal. The V finger and the ulnar half of the IV finger felt dry, suggesting slight hypohidrosis, but the ninhydrin-sweat test was negative.

The deep tendon and periosteal reflexes of the upper limb were normal. The groove of the ulnar nerve was normal apart from a skin scar after a boil. The abdominal skin reflexes were present. Patellar tendon reflexes were present and symmetric. The ankle jerk on the right side was more brisk than on the left. The plantar reflex on the right side was atypical and periodically positive. There was no paresis of the muscles of the lower limbs, but 10 cm over the patella the right thigh was 1.5 cm smaller in circumference than the left.

ELECTROMYOGRAPHY AND NERVE CONDUCTION VELOCITY

Electromyographic examination was performed. The muscles examined were the first dorsal interosseous muscle and the abductor muscle to the fifth finger on both hands. On the left side the electromyographic pattern was normal. On the right side there was a neurogenic affection with moderate loss of motor units, denervation potentials and fasciculation. The mean duration of the potentials was within normal limits.

Conclusion: neurogenic affection on right side. Nerve conduction velocity in both ulnar nerves measured from the region proximal to the sulcus nervi ulnaris to the wrist was normal (right nerve 53 m/sec, left nerve 58 m/sec) (sign H. J. Hansen).

Muscle biopsy The biopsy was taken from the right abductor digiti quinti muscle. The muscle had preserved longitudinal and transvers fiber bands. In some areas there were fibres of normal diameter. In other areas there was uniform atrophy of the fibers. The nuclei were pressed together, some of them were pyknotic and in a row. The connective tissue was normal. The amount of fat was normal. There was no sign of infection. Microscopical diagnosis: Neurogenic atrophy (sign Edith Reske Nielsen). X-ray studies of the cervical spine did not reveal any abnormality.

SIGNS AND SYMPTOMS

The symptoms and signs in the 20 cases from the literature (1, 2) and in our own case may be briefly summarized as follows:

Muscular atrophy The atrophy is unilateral and confined to the hand and part of the forearm. The brachioradial muscle had preserved its volume, so that the forearm seemed to be more slender in the mid-portion. Fascicular twitchings of the atrophied muscles were observed. The atrophy progressed for some years and then stopped. Tremorlike movements of the fingers were noted, especially when working in the cold with small tools. Motor weakness was always present and often one of the first symptoms, especially when closing and spreading the fingers. Some patients found it difficult to work with the affected hand, especially in cold weather.

Reflexes The deep tendon reflexes of the upper limb were usually symmetric. Abdominal skin reflexes were normal. In our patient there was a brisk ankle reflex on the affected side as in 2 cases of Hirayama and co-workers. They did not find positive Babinski reflex on the affected side. In our case there was an atypical plantar reflex on the affected side.

A sensory disturbance was noted in a few patients, hypesthesia in the affected hand but not in our case. In our case there was slight hy-pohidrosis of the V and half of the IV finger on the affected side. Hypohidrosis was noted once (case 8) by Hirayama and co-workers (2).

DIAGNOSTIC PROBLEMS

The diagnostic problems in our case were several. We first thought the disease to be early acute anterior poliomyelitis. There had not been any spell of fever, no polio epidemic or polio in the patient's relatives.

before onset of the disease. The stationary course together with the localized atrophy with unique distribution and the characteristic age of onset enabled differentiation from the spinal progressive muscular atrophy.

The slow progress, the cessation of the disease together with the age at onset argue against amyotrophic lateral sclerosis. The possibility of syringomyelia of the cervical cord was ruled out by the lack of sensory impairment. Cervical spondylosis and cervical rib were not seen. Hermitomyelia, multiple sclerosis and various kinds of inflammatory myelitis were differentiated by mode of onset and course.

Carpal tunnel syndrome was easy to exclude as were other peripheral nerve injuries. Atrophy in these disorders shows a different distribution and is accompanied by sensory disturbances.

The so called parietal atrophy described more than a century ago (?) may also be considered. This supranuclear lesion may lead to atrophy of the contralateral half of the body, or part of it. However, there is no phenomenon of denervation or fasciculation. Werdniger's disease can be ruled out by the age of onset. Myopathies such as progressive muscular dystrophy and myositis are easily excluded. The clinical course, the muscle biopsy and the electromyographic findings did not sustain the diagnosis.

The nature of the lesion and the cause of the disease are still unknown. Juvenile onset, stationary course and male sex preponderance are characteristic. No autopsy data are available. The final diagnosis should await complete pathologic studies.

SUMMARY

One case of juvenile muscular atrophy of unilateral upper extremity is described for the first time in Scandinavian literature. The case is discussed together with 20 cases found earlier in Japan. The disease is not inherited and predominantly males are affected. Juvenile onset, localized unilateral muscular atrophy, especially of the arm and non progressive course in the stage are cardinal features of this disorder. Electromyography demonstrates neurogenic affection and normal nerve conduction velocity in motor nerves. Muscle biopsy shows the picture of neurogenic atrophy. The disorder is distinctly different from any hitherto known entities of muscular atrophy. As yet no pathologic studies have been reported.

RESUME

Il est décrit pour la première fois dans la littérature scandinave un cas d'atrophie musculaire juvénile unilatérale de l'extrémité supérieure. Il est discuté de ce cas rapproché de 20 autres trouvés antérieurement au Japon. La maladie n'est pas héréditaire et elle atteint principalement le sexe male. Attaque juvénile, atrophie musculaire localisée notamment dans le bras d'un côté et n'ayant pas une évolution progressive dans le dernier stade sont les éléments cardinaux de ce trouble. L'électromyographie montre une affection neurogène et une vitesse de conduction normale des nerfs moteurs. Une biopsie du muscle donne le tableau d'une atrophie neurogène. Ce trouble est nettement différent de toute autre atrophie musculaire décrite jusqu'ici. Il n'a pas encore été effectué d'études pathologiques.

ZUSAMMENFASSUNG

Ein Fall von juveniler Muskelatrophie der oberen Gliedmasse einer Seite wird zum ersten Male in der skandinavischen Literatur beschrieben. Der Fall wird zusammen mit 20 Fällen, die früher in Japan gefunden wurden, besprochen. Die Krankheit wird nicht vererbt und männliche Personen werden vorzugsweise ergriffen. Beginn in der Jugend, örtliche Muskelatrophie, besonders im Arm einer Seite und nicht fortschreitender Verlauf im Spätstadium sind die Hauptzüge dieser Krankheit. Elektromyographie zeigt eine neurogene Affektion und normale Nervenleitungs geschwindigkeit in motorischen Nerven. Auf Muskelbiopsie gibt das Bild einer neurogenen Atrophie. Die Krankheit unterscheidet sich deutlich von allen bisher beschriebenen Formen muskularer Atrophie. Bis jetzt sind noch keine pathologischen Studien vorgenommen worden.

REFERENCES

1. Hirayama K., Toyokura Y. & Tsubasi T. (1963) Juvenile muscular atrophy of unilateral upper extremity. A new clinical entity. *Psychiat. Neurol. Jap.* 61: 2190.
2. Hirayama K., Tsubasi T., Toyokura Y. & Saito O. (1963) Juvenile muscular atrophy of unilateral upper extremity. *Neur. Med. Biol.* 12: 313-319.
3. Diamond, J. (1963) Neuromuscular disease. 21st Int. Congress of Neurology, Vienna 5-10/IX/1963, page 1-14.

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TUMOUR OF THE ULNAR NERVE

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Several papers have been written about paralysis of the ulnar nerve caused by mechanical pressure 1952 Seddon (6) gave a list including 4 cases caused by a ganglion and one case probably caused by a Dupuytren contracture

Brooks (1) gave a review of thirteen cases in which a ganglion in most cases coming from the neighbouring joint produced compression symptoms In 4 cases Brooks found a ganglion on the ulnar side of the elbow In 4 other cases he found ulnar affection from a typical ganglion compressing the ulnar nerve near the wrist or proximal in the palm In none of these cases was the ganglion found inside the nerve

A solitary tumour inside the deep branch of the ulnar nerve has been reported by Jenkins (2) The tumour was located inside the deep branch of the ulnar nerve with the nerve bundles spreading out over the surface of the tumour

In all together 7 Schwannomas of large nerve trunks Money (4) found pain in 5 cases the pain was of a sharp shooting character referring to the distribution of the affected nerve Paraesthesias were frequently noted Money (4) found no cases of Schwannoma with motor disturbance Peripheral nerve tumours are rare From 1910-1948 360 672 patients were admitted to the Royal Alfred Hospital Sydney and only 146 were found to have peripheral nerve tumours Carefully dissection of the nerve bundles away from the tumour was recommended by Jenkins (2) In malignancy the nerve trunk must be fully exposed above and below the tumour and no attempt made to save the nerve (Money (4))



Figure 1 The well circumscribed tumour located inside the ulnar nerve the nerve bundles spread out over and around the tumour (Onion like appearance)

Figure 2 The neural sheath was incised the nerve bundles retracted gently with hooks and the tumour could be removed

CASE REPORT

A thirty nine year old housewife came to the out patient clinic in November 1966 (case record no 131615). She complained of a lump situated above her left wrist on the volar aspect of the lower part of her left forearm. She had been aware of the lump for some years and it had grown especially the last few months. The lump was tender to direct trauma. The last couple of years there had been some paraesthesia to the fifth and the ulnar half of the fourth left finger. The patient had not noticed any weakness of the fingers. Except for some left knee trouble 3 years previously the patient had been healthy.

We found the patient to be healthy except for a plum sized tender tumour situated 6 cm above the left wrist over the ulnar part of the volar side of the forearm. The tumour was freely moveable and not adherent to the skin.

By compression of the tumour the patient complained of numbness of the fourth and fifth fingers. We did not find any other tumour localized to the subcutaneous tissue. The pre-operative diagnosis was a ganglion developing from the tendon sheaths.

The patient was scheduled for operation on 9th December 1966. As the patient had complained of paraesthesia the operation was performed under general anaesthesia. Before the operation the blood vessels in the arm were emptied. At the operation we found a well circumscribed tumour localized inside the ulnar nerve (Figure 1). The tumour was double with a narrow 1.5 cm long connection. The nerve bundles were spread out over and around the tumour and gave it an onion like appearance. The neural sheath was incised by a knife. With two hooks it was possible to split the sheath along the whole length of the tumour and with the hooks it was possible to retract the nerve bundles and the tumour could be easily removed (Figure 2). A narrow stalk located at the distal end of the tumour was cut through. After the operation the nerve bundles were undamaged. No attempt was made to suture the nerve sheath. Two weeks after the operation the skin sutures were removed the patient still had some paraesthesia but less than before the operation. There was no ulnar motor impairment no objectively

sensory disturbance. Microscopically the tumour was built up of fine thread like tissue woven together in bundles. In some places there was a plexiform structure. The cells which were elongated and spindle shaped were arranged like a palisade. No sign of malignancy. Microscopical Diagnosis: Neurinoma (Sign Tage Lund).

DISCUSSION

Several authors have tried to explain the origin of tumours in the peripheral nerves (1, 2, 4, 5). Our case was a typical tumour developing from the sheath cells of Schwann. There are two views on the origin of tumours of the nerve sheath. Stout (7) believed that the tumours are derived from the sheaths of Schwann.

The opposite view that these tumours arise from connective tissue is assumed by Mallory (3) and Penfield (5). In 3 cases Jenkins (2) found evidence suggesting that the tumours develop from the Schwann cells of the nerve sheaths and they should therefore be called neurilemmomas.

The tumours of the peripheral nerve are classified by Jenkins (2) as follows: 1) False neuroma, 2) Neurofibroma, 3) Neurilemmoma (Schwannomapalisade neuroma), 4) Neurofibrosarcoma.

In a neurofibroma the neurofibrils extend through the tumour but in the Schwannoma the neurofibrils are split and run outside and around the tumour. A Schwannoma often undergoes cystic degeneration. A Schwannoma is nearly always solitary. Jenkins (2) found that the lesion is benign. Wardle (8) is of the opinion that the neurilemmoma is of malignant nature. He presented 5 cases with a malignant picture with local recurrence and even one case with metastases from the sciatic nerve to the peritoneum. Two cases of malignant Schwannoma reported by Money (4) occurred in the sheath of the sciatic and posterior tibial nerves respectively.

SUMMARY

A case of a Schwannoma located in the left ulnar nerve at the wrist joint is reported. The operative technique and the microscopical appearance are described. The need for a careful case history and operation under general anaesthesia in a bloodless field is stressed.

RÉSUMÉ

Un cas de neurinome localisé dans le nerf cubital de l'articulation du poignet est rapporté. La technique opératoire et les découvertes micro-

scopiques sont décrites. La nécessité d'une observation minutieuse du cas et d'une opération sous anesthésie complète dans un champ vide de sang sont soulignées.

ZUSAMMENFASSUNG

Ein Fall von Schwannom des im n. ulnaris am Handgelenk gelegen war wird beschrieben. Die operative Technik und das mikroskopische Bild wird beschrieben. Die Notwendigkeit einer sorgfältigen Krankengeschichte und einer Operation bei voller Betäubung im blutlosen Feld wird hervorgehoben.

REFERENCES

- 1 Brooks H M (1952) Nervecompression by Simple Ganglion *J Bone Jt Surg* 34 B 391-400
- 2 Jenkins Aubrey S (1952) Solitary Tumours of Peripheral Nerve Trunks *J Bone Jt Surg* 34 B 401-411
- 3 Mallery F H (1920) The Type Cell of the So-called Dural Endothelioma. *J Med Res* 41 349
- 4 Moneys R A (1950) Tumours of Peripheral Nerves *New Z J Surg* 2 239-245
- 5 Penfield, W (1927) The Encapsulated Tumours of the Nervous System *Surg Gynec Obstet* 45 178
- 6 Seddon H J (1952) Carpal Ganglion as a Cause of Paralysis of the Deep Branch of the Ulnar Nerve *J Bone Jt Surg* 34 B 384-390
- 7 Stout, A P (1935) The Peripheral Manifestations of the Specific Nerve Sheath Tumour (Neurilemmoma) *Amer J Cancer* 24 751
- 8 Wardle E. V (1957-58) Peripheral Nerve Tumours *Brit J Surg* 45 58-61

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THROMBOSIS OF THE ULNAR ARTERY

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INTRODUCTION

Thrombosis or aneurysms in the arteries of the hand are not often mentioned in the literature and are perhaps seldom diagnosed. It seems that until the publication of an article by Kleinert & Voliantis in 1965 only about 100 cases had been published (Butsch & Janes 1963, Kleinert & Voliantis 1965). The disease was first described in the late 18th century by Guettani (ref Smith 1962) but apparently attracted little attention. In Scandinavia Rosen published a case as early as 1934. Leriche *et al* in 1937 mentioned the disease in their work on arterial resections in the treatment of peripheral vasospasm. For the past 20 to 30 years several reports of single cases have appeared: some of aneurysms (Middleton 1933, Smith 1962, Spittel 1958, Trevaslis *et al* 1964, Zuckerman & Proctor 1946) and some of thrombosis (Butsch & Janes 1963, Costigan *et al* 1959, Kleinert & Voliantis 1965, Spittel 1958). These cases were predominantly in the ulnar artery at the level of the carpal bones.

ANATOMY

The arcus volaris profundus receives its main supply from the radial artery while the arcus volaris superficialis gets its main supply from the ulnar artery. Before ending in the superficial arcus the ulnar artery sends its ramus profundus to the arcus volaris profundus. The ulnar artery passes deep to the short palmar muscle but superficially to the

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ligamentum carpi transversum. Here it is situated just radial to the superficial branch of the ulnar nerve which is predominantly a sensory nerve. Laterally it runs close to the pisiform bone and to the hamulus of hamatum. Since this location is close to the strong ligaments and bony structures it might have a bearing on the aetiology.

AETIOLOGY

The reason why thrombi and aneurysms form in this part of the ulnar artery is presumably because the artery in this area is especially exposed to trauma. It may be a question of repeated minor trauma as in monotonous work with consequent pressure of this segment of the ulnar artery against the deeper structures (e.g. working with pneumatic tools, gear shifts etc.). Or it may be a question of a more acute heavy trauma. Such trauma is described in many of the published cases (*Butsch & Janes 1963; Costigan et al 1959; Jackson 1954; Kleinert & Volantis 1965; Middleton 1933; v Rosen 1934; Smith 1962; Trevasakis et al 1964; Zuckerman & Proctor 1946*). Since such trauma is very common it seems strange that the disease does not occur more often. The explanation might be that the relationship to trauma is not so precise or that the disease is more common than supposed and that it is often misdiagnosed.

PATHOGENESIS

The formation of thrombi is presumably due to lesions of the intima and the formation of aneurysms seems to occur mainly through lesions of the tunica media (*v Rosen 1934*). Aneurysms might also be congenital but in fact most aneurysms seem to be of true acquired type and in some cases they are thrombosed.

SYMPTOMATOLOGY

The symptoms may vary considerably. The patient will often complain that a tender, tense tumour has developed in the hypothenar region, a sign which usually appears early in the disease. Besides there are often marked episodes of vasospasm. The patient will exhibit Raynaud's phenomenon and complain of pale and dead fingers especially when working or exposed to the cold. The pectoral might be accompanied by aching pain, a sensation of burning and cyanosis. In severe cases ulceration or gangrene may develop. Neurological symptoms such as par-

aesthesia and hyperaesthesia in the sensory area of the ulnar nerve occurs perhaps because of the close anatomical relationship between the diseased artery and the superficial branch of the ulnar nerve which may be compressed or irritated by aseptic inflammatory reactions around the thrombosed artery

DIAGNOSIS

The diagnosis is made from the history the subjective complaints mentioned above and a positive Allen test This test is nearly always positive when the ulnar artery is thrombosed If there is a non thrombosed aneurysm a swelling can be seen which disappears when the artery is compressed above the site In such cases a bruit is often heard over the swelling

ALLEN TEST

This test is performed by compressing the radial artery at the wrist while the patient forcibly opens and closes the hand a few times Normally a slight transitory ischaemia will be seen which disappears quickly when the hand is kept still and compression maintained When the ulnar artery is not functioning due to thrombosis the pallor will persist for a long time during continued compression of the radial artery and marked ischaemic pallor will be seen In such cases the test is said to be positive During this final part of the examination the fingers should not be hyperextended since such hyperextension will result in a false positive reaction

Positive results of the Allen test will be sufficient to make the diagnosis Further evidence can be obtained by brachial arteriography Many authors emphasize that this is hardly necessary and a few authors warn against this method because of the possibility of provoking vasospasm which might lead to an exacerbation of the disease One participant in a discussion at the Mayo Clinic (*J W Lord* quoted by *Butsch & Janes* 1963) mentioned a case where gangrene developed after arteriography

TREATMENT

The treatment of this disease varies It may be by conservative methods using vasodilators anti coagulants or perhaps even steroid drugs and cessation of smoking In addition conservative surgical treatment such as sympathectomy performed after a good response to injection of the

stellate ganglion has been shown to be effective but not uniformly so because sympathectomy will eliminate vasoconstriction and does not stimulate the vasodilator apparatus (Bulsch & Janes 1963)

Finally there is radical surgical treatment consisting of resection of the injured part of the ulnar artery followed by ligation of the ends. The ultimate objective is (Ierliche 1937) to remove the part of a vessel which is thought to provoke the vasospasm and to encourage the formation of collaterals. This treatment has been used effectively in the majority of reported cases. Furthermore surgical treatment may be conservative with multiple arteriotomies and endarterectomies or resection of the thrombosed area and end-to-end anastomosis of the vessel. This latter method has been successfully used by Kleinert & Volantts (1965) in 9 cases. The authors did not follow up the patients arteriographically but reported a good result in a case where the Allen test again had proved positive.

It is still debatable whether this treatment is superior to resection and ligation.

CASE REPORTS

The disease is more common than what is indicated by the number of single cases reported. During the period of about one year we observed 3 cases which are described below.

Case 1 A 49 year old labourer whose mother had a tendency to vasospasm in the fingers. In 1959 the second right finger was amputated after an accident. On admission to hospital on 6th December 1961 he complained of prickling pain of about one year's duration in the middle and ring fingers of his right hand. The attacks occurred 1 to 3 times a day and lasted from 5 minutes to 2 hours. During the attacks the fingers were pale and the spasms were followed by paraesthesia and pain. Cold and hard work provoked the attacks. No symptoms were seen in the other hand or in the lower extremities. At the onset of symptoms the patient noticed swelling of the hand and lower forearm. Vasodilators were tried but without success. In his work he had been using pneumatic tools. Before he was admitted to hospital he had been incapable of working for about 9 months.

Physical findings Slight arteriosclerotic changes at ophthalmoscopy. No evidence of costoclavicular arterial compression. Slight cyanosis in the middle and ring fingers of the right hand. No trophic changes. Allen test was positive on the right side and negative on the left.

The diagnosis of thrombosis of the ulnar artery was based on the criteria mentioned above. The patient had been treated with infiltration of the stellate ganglion with a good but transitory response. Transferred to the neurosurgical department County Hospital Glostrup he was examined with brachial arteriograph which showed evidence of thrombosis at the level of the carpal bones (Figure 1).

A right thoracic sympathectomy of the 2, 3 and 4 ganglion was performed with an immediate and good relief of the symptoms. After the operation some

Figure 1 Brachial arteriogram showing occlusion of the ulnar artery at the carpus (Case 1)



neuralgic pains developed due probably to a slight contusion of the brachial plexus during operation. Four months after operation when the patient was reexamined the neuralgic pains had subsided and the vasospastic symptoms had disappeared but the Allen test was still positive. The prognosis is thought to be good. If the symptoms recur regional resection of the ulnar artery will be offered.

Case III A 66 year old man who is a small holder. Six months before admission to hospital he was operated on because of benign pyloric stenosis. Three months before presentation without preceding trauma he noticed an increasing somewhat tender swelling of the base of the left hypothenar region. The swelling persisted for about 2 months. No signs of vasospasm.

Physical signs On February 15 1966 before admission to hospital a slight tender lump of 2 by 1 cm in size was found at the base of the left hypothenar region. It was deep seated not movable and not circumscribed. The diagnosis was thought to be a deep seated ganglion. When admitted to hospital on 1st March 1966 the lump and tenderness had decreased. He was operated upon three days later using a bloodless field. It was then found that the ulnar artery was thrombosed and a small embolus proximal to the thrombosed area was noticed. The pathological changes were spread only in the area of the ramus superficialis. The artery was normal where the profound branch was given off. A slight inflammatory reaction oedema discoloration of the fat and a little serous fluid was found around the vessel. The superficial branch of the ulnar nerve was intact. Distal to the thrombosed area the artery was likewise normal (Figure 2). A small arteriotomy was done. The degenerated intima was removed together with the embolus. After suture of the incision with atraumatic silk no 00000 the blood flow was excellent through the artery so that regional resection was not performed. In the post operative phase the patient had a little stiffness of the fingers which improved steadily with exercise and physiotherapy and a slight paraesthesia in the ulnar area which subsided soon.



Figure 2. Operative findings in Case 2 showing occlusion of the ramus superficialis of the ulnar artery. The thrombosed area is seen between the slings along the superficial branch of the ulnar nerve is exposed.

taneously. These symptoms were not present before the operation. The Allen test had not been performed before operation because vasospasm had not been present and the disease had been misdiagnosed as a ganglion. One month later the positive Allen test showed evidence that the artery had thrombosed again. If vasospastic symptoms recur we shall consider reoperation and resection of the diseased part of the artery. This patient has no history of heavy or repeated minor trauma. He is a farmer, however, accustomed to heavy work, and he is left-handed.

Case 3. A 26 years old man of low intelligence. On 20th May 1968 he sustained a heavy blow against the left hand on the volar side of the wrist. X ray revealed no fracture. Swelling and ecchymosis were present and the patient was treated by his general practitioner for sprain of the wrist. One week later there was some stiffness of the fingers together with tingling and hypaesthesia on the volar aspects of the three ulnar fingers. The patient was treated with ultrasonic waves and finger exercises. The condition of his fingers varied during this period. He complained of coldness of the fingers which were from time to time cyanotic but actual vasospastic attacks were difficult to trace because of his poor intellect. Pulsation was felt in the radial artery at the wrist but not in the ulnar artery. 5 months after the trauma further exacerbation of the symptoms with attacks of cyanosis, pains and swelling occurred. Slight hyperhidrosis and some atrophy of the skin were present, no radiological signs of Sudeck's atrophy were seen. The patient was again admitted to hospital and 6 injections of the stellate ganglion were given. Percutaneous brachial arteriography showed filling of the arcus volaris profundus from the radial artery but no filling in the arcus volaris superficialis. Nevertheless, there was filling of the very ulnar part of the superficial branch of the ulnar artery. Injections of the stellate ganglion were continued and anti-coagulating therapy was started simultaneously. After 7 months, there was improvement and at the last follow up there were no signs of Sudeck's atrophy.

Figure 1 Brachial arteriogram showing occlusion of the ulnar artery at the carpus (Case 1)



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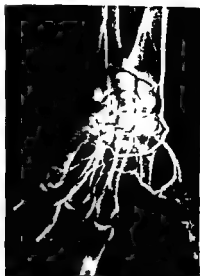


Figure 2 Operative findings in Case 2 showing occlusion of the ramus superficialis of the ulnar artery. The thrombosed area is seen between the slings ulnarly the superficial branch of the ulnar nerve is exposed.

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neuralgic pains developed due probably to a slight contusion of the brachial plexus during operation. Four months after operation when the patient was reexamined, the neuralgic pains had subsided and the vasospastic symptoms had disappeared, but the Allen test was still positive. The prognosis is thought to be good. If the symptoms recur regional resection of the ulnar artery will be offered.

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Physical signs. On February 15 1966 before admission to hospital a slight tender lump of 2 by 1 cm in size was found at the base of the left hypothenar region. It was deep seated not movable and not circumscribed. The diagnosis was thought to be a deep seated ganglion. When admitted to hospital on 1st March 1966 the lump and tenderness had decreased. He was operated upon three days later using a bloodless field. It was then found that the ulnar artery was thrombosed and a small embolus proximal to the thrombosed area was noticed. The pathological changes were spread only in the area of the ramus superficialis. The artery was normal where the profound branch was given off. A slight inflammatory reaction, oedema, discoloration of the fat and a little serous fluid was found around the vessel. The superficial branch of the ulnar nerve was intact. Distal to the thrombosed area the artery was likewise normal (Figure 2). A small arteriotomy was done. The degenerated intima was removed together with the embolus. After suture of the incision with atraumatic silk no. 00000 the blood flow was excellent through the artery so that regional resection was not performed. In the post operative phase the patient had a little stiffness of the fingers which improved steadily with exercise and physiotherapy and a slight paraesthesia in the ulnar area which subsided upon

RESUME

Description d'une thrombose de l'artere cubitale Comme la formation d'un anevrisme dans cette artere la maladie semble souvent avoir une etiology traumatique Il est discute de la base anatomique de l'etiology et de la pathogenese ■ cas sont rapportés Le diagnostic a ete verifié par l'operation l'arteriographie et en particulier par un test Allen positif Il est souligne que la maladie est plus frequente qu'on ne le suppose généralement et qu'elle est souvent mal diagnostiquée

ZUSAMMENFASSUNG

Eine Beschreibung der Thrombose der a ulnaris wird gegeben Die Erkrankung scheint ebenso wie die Bildung eines Aneurismas in dieser Arterie oft auf traumatischer Grundlage zu entstehen Die anatomische Basis die Athiologie und die Pathogenese werden besprochen ■ Falle werden berichtet Die Diagnose wurde durch die Operation die Arteriographie und besonders durch eine positive Allen Probe bestätigt

REFERENCES

- Allen E V, Barker W & Hines E A (1969) Peripheral vascular diseases 3rd ed p 123-179 and p 456-458 Saunders Phil & London
- Butsch J L & Jones J W (1963) Injuries of the superficial palmar arch. *J Trauma* 3 505-517
- Costigan D G, Riley J W & Cox F E. (1959) Thrombofibrosis of the ulnar artery in the palm. *J Bone Jt Surg* 41A 699-700
- Cardner C (1959) Traumatic vasospasm and its complications. *Amer J Surg* 83 468-470
- Jackson J P (1954) Traumatic thrombosis of the ulnar artery in the palm. *J Bone Jt Surg* 36B 435-439
- Kleinert, H E & Volantis J J (1965) Thrombosis of the palmar arterial arch and its tributaries Etiology and newer concepts in treatment. *J Trauma* 5 446-457
- Leriche, R, Fontaine R & Dupertuis S W (1937) Arterectomy with follow up studies on 28 operations. *Surg Gynec Obstet* 64 149-155
- Middleton H (1933) Occupational aneurysm of the palmar arteries. *Brit J Surg* 21 215-218
- Rosen S (1934) Ein Fall von Thrombose in der A. Ulnaris nach Einwirkung von stumpfer Gewalt. *Acta chir scand* 73 500-503
- Smith J W (1969) True aneurysms of traumatic origin in the palm. *Amer J Surg* 104 7-14
- Spittel J A (1958) Aneurysms of the hand and wrist. *Med Clin N Amer* 42 1007-1011
- Trevaskis A, Marks K W, Pennisi A W & Berg E W (1964) Thrombosis of the ulnar artery in the hand. *Plast reconstr Surg* 33 73-77
- Zuckerman I C & Proctor S E (1946) Traumatic palmar aneurysm. *Amer J Surg* 72 52-56

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OSTEOARTHRITIS OF THE TRAPEZIO SCAPHOID JOINT

By

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Degenerative changes in the carpal joints are common and often the cause of disabling pain which seriously interferes with function. Of the midcarpal joints those into which the greater multangular bone enters appear to be most commonly affected. Much attention has been given to the carpo metacarpal (CMC) joint of the thumb one of the most frequent localizations of primary osteoarthritis (*Lasserre et al* 1949 *Brailsford* 1953, *Aune* 1955 and others). The purpose of this article is to emphasize a condition which as far as we can find from the literature has attracted no attention. This concerns the *isolated* osteoarthritis of the trapezio scaphoid (TS) joint of the wrist (Figures 1 and 2). Our interest was aroused by finding this particular localization of joint degeneration in patients complaining of radial volar swelling at wrist level clinically with appearance of a ganglion. It was found by contrast injection into the carpal joint that as a rule communication existed between the diseased TS joint and the space surrounding the flexor carpi radialis (FCR) tendon (Figure 3).

Anatomically the trapezium is an intermediate bone placed in a vulnerable position between the first metacarpal and the scaphoid. Adjacent to the volar aspect of the bone lies the tendon of the FCR which inserts at the base of the second metacarpal (Figure 4).

It is well known to everyone who deals with hand surgery that radial volar ganglia differ in character from dorsal wrist ganglia. They usually have thin walls they may be polycystic and are often intimately connected with the FCR tendon and disappear distally into the carpus along the tendon. They may contain the same type of jelly or fluid as dorsal ganglia.

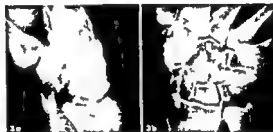
Figure 1 Local osteoarthritis between the trapezium and the scaphoid

*a) radial flexion of the wrist
b) ulnar flexion of the wrist*



Figure 2 Advanced osteoarthritis of the trapezio scaphoid joint

*Figure 3 a) Lateral view Contrast leaking out around the tendon of flexor carpi radialis
b) Frontal view same case*



*Figure 4 a) Volar flexion Contrast leaking up along the flexor carpi radialis tendon to mid level of forearm
b) Dorsal flexion same case*

CLINICAL MATERIAL

Since our attention was directed to the possible connection between volar "ganglion" and osteoarthritis in the T-S joint we have radiographically examined patients with radial volar swellings at the wrist

In order to get an idea of the incidence of isolated osteoarthritis in the T-S joint among patients with this condition and above 30 years of age a follow up study was made of the cases seen in our department during the last 15 years

Those who revealed degenerative changes in the T-S joint underwent arthrography whereby the contrast medium usually was injected into the carpal joint from the dorsal aspect of the wrist. Some patients with radial volar swelling but without radiological carpal changes were also examined by arthrography representing the controls.

Table 1 Cases with osteoarthritis in T-S joint

Case No	Age	Sex	Initial sympt.		Osteo arthritis		Volar tumor at time of arthrography	Operated	Arthrography		Comments
			Volar tumor	Pain	CMC	T-S			Contrast around FCR	Contrast in gangl	
1	66	F	+	+	(+)	+	+			+	
2	68	F	+		+	+		+	+		
3	40	F		+		+			+		
4	64	F	+	+		+	+		+		
5	59	F	+	+		+		+	+		
6	66	F	+	+	+	+		+	+		
7	79	F	+	+		+		+	+		
8	68	F	+	+		+	+		+		
9	68	F	+	+		+	+		+		
10	70	F		+		+			+		
11	77	F	+			+	+			+	
12	82	F	+	+		+	+		+		
13	63	F	+	+		+	+		+		
14	50	F	+	+		+		+			
15	55	F	+	+		+	+		?		No arthrography
15	60	F	13	13	3	15	8	5	11	2	

RESULTS

A total of 48 cases were examined. Isolated osteoarthritis of the T-S joint was found in 12 cases while 3 cases had additional changes in the CMC joint of the thumb. Isolated changes in the first CMC joint were found in 5 cases while the rest of the 28 cases had normal radiological findings (Table 1).

The cases with affection of the T-S joint are listed in Table 1. All patients are female and middle aged. Most of them complained of pain and local swelling at wrist level. Contrast filling of the peritendinous space of FCR was found in 11 cases. The contrast followed the tendon

in a proximal direction ultimately visualizing the clinically found wrist swelling. In some cases the contrast even followed the tendon to the mid level of the forearm. In 2 cases a ganglion was filled without contrast leaking out around the tendon and in 1 case finally arthrography was not done. Thus in one case only communication could not be demonstrated between the diseased T S joint and the peritendinous space or the volar swelling respectively. Six cases with radial volar wrist swelling but normal radiological findings were also examined with contrast injection into the carpus. In 5 of these normal arthrography was found while in the sixth case contrast was found around the FRC-tendon. It should be mentioned however that this patient had been operated several times for recurring ganglion at this site.

DISCUSSION

The numerous theories about ganglia found in the literature testify to the lack of agreement concerning the aetiology of this condition. It is reasonable to assume that no single explanation can be given. Whatever the cause may be however it seems probable from their proximity to joints that ganglia bear some relationship to synovial fluid. From the findings in the present investigation it seems quite clear that a great number of so called radial volar wrist ganglia have a definite relationship to localized degenerative changes in the T S joint.

The frequency of primary osteoarthritis of the CMC joint of the thumb has been pointed out by most authors dealing with this subject. According to the present observations isolated changes in the T S joint are not uncommon and it is therefore curious that this condition seems to have been overlooked. The clinical aspect of the condition has an interesting difference from osteoarthritis in the CMC joint in that it frequently gives rise to the above described volar wrist swelling.

Considering the nature of this progressive degenerative joint disease it is not difficult to conceive that a rupture of the fibres of the T S joint capsule may easily be produced. This would allow synovial fluid to escape from the joint and by the movements of the wrist to be forced into the peritendinous tissue. At this point the FRC tendon comes in close contact with the joint capsule on its way to insertion on the second metacarpal. The synovial fluid may follow the tendon proximally and finally become of clinical significance as a ganglionlike soft tissue tumor at wrist level.

At least in middle aged and older females before the surgeon operates

for volar radial wrist ganglia it is recommended that he looks for radiological changes in the T-S joint. When changes are obvious arthrograms of this joint should be made.

SUMMARY

Localized degenerative changes in the trapezio scaphoid joint have been observed in middle aged females who complain of wrist pain and have a volar radial swelling at wrist level. Arthrographic studies have revealed communication between this diseased joint and the peritendinous space of the flexor carpi radialis clinically often appearing as a ganglionlike swelling. The pathophysiology is discussed.

RESUME

Des modifications dégénératives localisées dans l'articulation trapezo scaphoïdienne ont été observées chez des femmes d'un certain âge qui se plaignent de douleurs dans le poignet et qui ont une enflure palmaire radiale au niveau du poignet. Des études arthrographiques ont révélé un rapport entre cette maladie articulaire et l'espace peritendineux du flechisseur carpi radial apparaissant souvent en clinique sous la forme d'une enflure ganglionnaire. Il est discuté de la pathophysiologie de la maladie.

ZUSAMMENFASSUNG

Ortliche degenerative Veränderungen im multangulumscapholare Gelenk wurden bei Frauen im mittleren Alter die über Handgelenks schmerzen klagen und eine volare radiale Schwellung in der Höhe des Handgelenkes haben beobachtet. Arthrographische Untersuchungen haben eine Verbindung zwischen diese erkrankten Gelenke und dem peritendinösen Raum des Flexor carpi radialis gezeigt was sich klinisch oft in einer ganglionartigen Schwellung aussert. Die Pathophysiologie wird besprochen.

REFERENCES

1. Aune H (1955) Osteoarthritis of the First Carpo Metacarpal Joint. *Acta chirurgica* 109: 449.
2. Brailsford J F (1953) *Radiology of Bones and Joints* P 98 J A Churchill Ltd
3. Lasserre Ch, Panzai D & Derennes H (1949) Osteoarthritis of the Trapezio Metacarpal Joint. *J Bone Jt Surg* 31 B: 537.

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KIENBOECK'S DISEASE TREATED WITH OSTEOTOMY TO LENGTHEN ULNA

By

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Received 7 III 67

The first report of chronic progressive osteochondrosis of the carpal lunate bone was reported by *Kienboeck* in 1910 since when various hypotheses have been put forward to explain the disease and several methods of treatment have been suggested. *Kienboeck's* conception of the disease as primary necrosis because of a circulatory disorder with secondary fractures has long been refuted as have other theories such as *Axhausen's* which ascribes the necrosis to mycotic embolism. According to the present consensus of opinion the cause of the condition is a primary compression fracture with interruption of some or all of the blood vessels reaching the lunate bone through its volar and dorsal surfaces. This conception is supported by the work of *Stahl* (1947). He and others who have studied the physiology and mechanics of the wrist have shown that this bone is acted upon by the majority of local forces arising on movement of the hand and wrist and is therefore exposed to the risk of injury.

Hultén (1928) stressed that the lunate bone faces the articular surface of the radius and the triangular disc which consist of much softer tissue. A further anatomic feature of importance in the causation of the disease is according to *Hultén* shortness of the ulna relative to the radius so-called minus variation which places an abnormal strain and stress on the lunate bone. Of 400 normal wrists *Hultén* found minus variation in 23 per cent no variation i.e. articular surface of radius and ulna at the same level—in 61 per cent and relative shortness of the radius relative to the ulna—minus variation in 16 per cent. Of 23 patients with osteochondrosis of the lunate bone they found minus variation in 74 per cent no variation in 26 per cent and no plus

variants In a compilation of 338 cases from the literature *Persson* (1945) found minus variation in 60 per cent and no variation in 40 per cent and plus variation in none *Stahl* has shown that plus variation may sometimes occur although rarely Another argument for the fracture theory is that the disease occurs mostly in men and then as a rule in the hand used most i.e. generally the right one

TREATMENT (Table 1)

Table 1 Results obtained with different methods of treatment

	Elongation osteotomies				
	Excision of lunate bone	Lunate bone replaced by prosthesis	Immobilisation in plaster	Literature cases	Personal cases
Number of cases	60	17	293	54	10
Average interval between operation and review (years)	6	4½	10	6	13½
Arthrosis of the wrist (in % of total)	90-100	90-100	80-90	30	20
No significant symptoms (%)	54	53	31	100	100
Symptoms reducing function (%)	12	24	38	6	0
Disabling (%)	34	23	31	4	0

Conservative The commonest and oldest type of treatment consists of immobilisation in plaster In a compilation of literature cases *Persson* (1945) found this method to have produced a good result without any significant persistent symptoms in 49 improvement but symptoms in association with heavy work in 57 and poor results or complete loss of function of the wrist in 56 In *Stahl's* (1947) series of 142 patients all pain disappeared in 31 71 had pain on movement of the wrist and 13 were obliged to change their occupation but arthrosis deformans of the radio-carpal joint was seen in as many as 94 of 104 examined *Stahl* concluded that when the wrist was immobilised for less than 2 months the result was poor in every second patient but in only every sixth when the wrist was immobilised for a longer period

Excision of the lunate bone According to *Campbell et al* (1964)

Stahl (1947) and *Besutti* (1964) the end results of excision of the lunate bone are poor. *Dornam* (1949) and *Gillespie* (1961) however reported good results the latter in 21 of 24 cases though they like other authors invariably observed progressive arthrosis and stiffness of the wrist. The general consensus today is that excision of the lunate bone is a mutilating operation with serious secondary changes in the wrist and that it is therefore no longer justified.

Replacement of lunate bone by an artificial substitute This operation was performed with success on 1 patient reported by *Danis* (1951). *Agarholm & Goodfellow* (1963) reported 15 cases where the lunate bone was replaced by an acrylic prosthesis. 13 of the patients were satisfied with the result. 8 were symptomfree and 7 had only mild symptoms but this operation too was invariably followed by progressive arthrosis of the wrist.

Osteotomy for lengthening the ulna In view of *Hultén's* theory of the abnormal loading of the lunate bone especially if the ulna is short *Persson* described a method for lengthening the ulna distally. the lunate bone is unloaded to promote healing with minimum secondary arthrosis of the wrist. In 1945 *Persson* described his method and the results obtained in 10 patients operated upon and 5 years later he reported a further 14 cases in most of which the results were good. *Desenfans* (1953), *Leitner* (1954), *Verbrugge & Verjans* (1963) and *Besutti* (1964) also reported cases treated successfully by this method.

Judging from the literature then osteotomy produces satisfactory results more often than other methods available for the treatment of the condition.

PREFSENT SERIES (Table 2)

Nine patients with Kienboeck's disease which was bilateral in one of them were treated with osteotomy of the ulna *ad modum* *Persson*. Three of the patients were below 20 five were between 20 and 30 and one was above 30 years. One patient was left handed. He and one patient who was right handed were operated upon on the left side. the remaining 7 on the right side. One of the patients was a woman the remaining 8 were men with heavy manual occupations. Four had trauma in their histories. Before the operation 4 of the wrists showed no variation and 5 showed minus variation. There were no plus variants. Seven wrists had been treated for 2-8 months previously with immobilisation but without success. Only 1 of the wrists had produced symptoms for more

Table 2

Sex	M		F		M		M		M		M		M		Sum	
	I	R	I	R	I	R	I	R	I	R	I	R	I	R	M	V
Side	18	19	19	19	19	19	19	19	19	17	5	14	4	1 ¹ / ₂	11 ¹ / ₂	M = 13 ¹ / ₂
Follow up period in years	/	/	/	/	/	/	/	/	/	/	/	X	-	/	-	6
Tenderness on palpation	/	/	/	/	/	/	/	/	/	/	/	/	-	-	-	8
Intermittent pain	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	7
Heavy occupation	/	/	/	/	/	/	/	/	/	/	/	/	-	/	/	9
Wrist stronger than before operation	/	/	/	/	/	/	/	/	/	/	/	/	-	-	-	
Dynamometer in % of contralateral hand	63	40	100	100	100	100	97	-	-	100	88	110	110	M = 70		

$$Y = Y_{\text{can}}$$

than 1 year. The interval between the operation and the present review was on the average $13\frac{1}{4}$ years.

OPERATION TECHNIQUE

The operation was usually performed under plexus or axillary blockade sometimes in a bloodless field. An incision about 10 cm long was made along the subcutaneous border of the ulna down towards the styloid process of the ulna and the ulna was dissected and exposed subperiosteally. To obtain stability after the osteotomy and a rough surface to promote healing the bone was cut obliquely with a chisel through a 10 cm premarked line along which a number of holes had been drilled to facilitate the chiselling and to prevent the bone from splitting. The purpose was to secure a plus variation of 3–4 mm. After the desired increase in length of the bone was calculated holes were drilled in the radioulnar direction in the distal and proximal fragments respectively, the level between consecutive holes being equal to the distance the bone was to be lengthened (Figure 1). A piece of wire was threaded through the holes and with the aid of a wire twister desired lengthening could be easily obtained. If the osteotomy is placed in the way illustrated in Figure 1 the distal fragment can be readily gripped with a single pronated hook and retracted with simultaneous radial deviation of the wrist to facilitate the lengthening still more. According to *Desenfans*, *Verbrugghe* and *Verjans* the method has fallen into disrepute because of the difficulty in obtaining the desired elongation. They therefore recommend step osteotomy and the use of a Duchene plate for fixation. But with this procedure the osteotomy is still more unstable and the presence of the plate on subcutaneous bone retards healing of the skin, a side effect that occurred also in the *Verbrugghe* and *Verjans* series. But if the above method is applied strictly according to instructions extension is readily obtained and good stability can be obtained by the use of 2 supplementary cerclages. The rough chiselled and bored osteotomy prevents slipping and at the same time promotes healing.

After the operation a dorsal plaster splint is applied from the metacarpophalangeal joints to half way up the overarm with the elbow flexed 90° and the hand in midposition between pronation and supination. After about 2 weeks the sutures are drawn and the splint is replaced by a circular plaster after which the patient may be treated at the outpatient department for 8 weeks after the operation by which time the osteotomy has usually healed. In the present material the bone

(Table 3) On the other hand ulnar and radial deviation as well as pronation and supination were barely affected

Table 3 Impairment of mobility in degrees compared with range of motion of contralateral wrist

	0	5	10	15	20	25	30	Mean
Dorsal flexion	3	2	2	1	0	2	0	9
Volar flexion	2	1	4	0	1	1	1	11
Ulnar deviation	2	0	2	0	1	0	0	3
Radial Deviation	3	2						1
Pronation	3	6	1					4
Supination	9	1						1

Roentgenography showed that all the osteotomies had healed normally. In 7 cases the structure of the lunate bone had improved (Table 4) with healing of the fragments and of the cysts (Figures 2-3) in 1 case the structure was unchanged and in 2 the structure had deteriorated with increase of the cysts in one with both increase of the cyst and with fragmentation in the other. These changes had no appreciable effect on the function of the hand and the patients were still carrying on with their usual heavy manual occupation. So were the 2 patients who had mild arthrosis of the radio carpal joints with marginal sclerosis and 1 patient with narrowing of the joint space between the naviculare and

Table 4 Cases arranged in same order as in Table 3

Increase in length of ulna	2-3 mm									\	—	X	2
	4-5 mm	\	\	\	\	X	\	X		—		7	
Increase in proximo distal dimension of lunate bone		0	+	+	+	+	+	+	0	0	0	6	
Improvement of structure of lunate bone		+	0	+	+	+	+	+	—	—	+	7	
Radio carpal arthrosis		\					X					2	
Arthrosis between navicular and trapezoidum				\								1	



Figure 2 A wrist with Kienboeck's disease immediately before operation (left) and a review 13 years later (to right)



Figure 3 Lunate bone immediately before operation (left) and at review 17 years later (to right) Note the elongation of ulna

the trapezoidium. Though not arthrotic the navicular and the trapezoidium showed sharp edges in 8 wrists and the triquetrum and hamatum in 2. These changes may perhaps be ascribed to the changes in the mechanics and loading of the wrist. *Restitutio ad integrum* was not observed in any of the cases. Neither could complete recovery be expected for the fractures were not reduced and were thus left to heal in their compressed state. In 6 cases the proximo distal dimension of the lunate bone had however increased in thickness in 4 it was the same as before the operation and in none had it become shorter.

All of the patients were very satisfied with the result of the operation. Two who had however been obliged to take lighter work still thought that they could use the hand unhindered. The remaining 7 had returned to their previous heavy work in the woods and on the land.

SUMMARY

Nine patients (10 wrists) with Kienboeck's disease treated with osteotomy for lengthening the ulna *ad modum* Persson are described. The patients were reviewed on the average $13\frac{1}{2}$ years after the operation. The clinical end results were very good and all the patients were satis-

fied. In none of the cases did roentgenography show such severe arthrosis of the radio-carpal joint as that seen after treatment with other methods.

Judging from published reports and the cases described here osteotomy is the best available method in the treatment of the condition.

RESUME

Neuf malades (10 poignets) souffrant de la maladie de Kienboeck ont été traités par ostéotomie pour allonger le cubitus d'après la méthode Persson. Il est donnée une description de ces cas. Les malades ont été réexaminés au bout d'une période moyenne de 13 ans et demi après l'opération. Les résultats finaux cliniques étaient excellents et tous les malades étaient satisfaits. Dans aucun des cas la radiographie ne montra une arthrose grave de l'articulation radio-carpeale que l'on rencontre souvent après le traitement par d'autres méthodes.

À en juger des rapports publiés et des cas décrits ici l'ostéotomie est la meilleure méthode de traitement à disposition dans ces circonstances.

ZUSAMMENFASSUNG

Neun Patienten (10 Handgelenke) mit Kienboeck's Erkrankung die mittels Osteotomie zur Verlängerung der Ulna *ad modum* Persson behandelt wurden, werden beschrieben. Die Patienten wurden durchschnittlich 13½ Jahre nach der Operation untersucht. Die klinischen Resultate waren sehr gut und alle Patienten waren zufrieden. In keinem der Fälle zeigte die Röntgeuntersuchung so schwere Arthrosen des Radio-carpalgelenkes als die welche man nach Behandlung mit anderen Methoden beobachtet.

Gemäss veröffentlichten Berichten und den hier beschriebenen Fällen ist die Osteotomie die am besten anwendbare Methode in der Behandlung dieses Zustandes.

REFERENCES

1. Agerholm J. C. & Goodfellow J. M. (1963) Avascular Necrosis of the Lunate Bone Treated by Excision and Prosthetic Replacement. *J. Bone Jt. Surg.* 45B 110-116.
2. Besutti A. (1964) Sul Trattamento della Malacia del Semilunare. *Minerva ortop.* 16 87-89.
3. Campbell Jr. R., Lange E. & Chiswick (1964) Lunate and Triquetral Dislocations. *J. Bone Jt. Surg.* 46B 55-72.

- 4 Desenfans G (1961) A propos de la Maladie du Semi lunaire Operation de Persson *Acta chir belg* B 1 58-61
- 5 Gillispie H S (1961) Excision of the Lunate Bone in Kienboeck Disease *J Bone Jt Surg* 43B 245-249
- 6 Hultén O (1928) Über Anatomische Variation der Handgelenkknöchen Ein Beitrag zur Kenntnis der Genese zweier verschiedener Mondbeinveränderungen *Acta radiol* B 9 155
- 7 Hultén O (1935) Über die Entstehung und Behandlung der Lunatummalazie (Morbus Kienboeck) *Acta chir scand* B 76 121-135
- 8 Kienboeck R (1910) Über Traumatische Malazie des Mondbeins und ihre Folgezustände *Fortschr Röntgenstr* B 16 77-115
- 9 Leitner B (1954) Sulla Cura dell'Osteomalacia del Semilunare col Metodo di Persson *Arch Fatti* B 5 234-240
- 10 Persson M (1945) Pathogenese und Behandlung der Kienboeckchen Lunatummalazie *Acta chir scand* B 92 Suppl 98
- 11 Persson M (1950) Casual Treatment of Lunatomalacia Further Experiences of Operative Ulna Lengthening *Acta chir scand* B 100 531-544
- 12 Ståhl G (1947) On Lunatomalacia A Clinical and Roentgenological Study especially on its Pathogenesis and the Late Results of Immobilization Treatment *Acta chir scand* B 95 Suppl 126
- 13 Verbrugge J & Verjans H (1963) L'allongement du cubitus comme Traitement de Choix de la Maladie de Kienboeck. *Rev chir orthop* B 49 563-576

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FLEXOR TENDON GRAFTS

Results in 95 Cases

By

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Received III VII 67

After the technique of free tendon grafting has gradually become so firmly established that the operation is a routine procedure it has been introduced in several departments all over Denmark. In this connection it is perhaps of interest to ascertain the results obtained in a department of general orthopaedic surgery by this operation considered by many hand surgeons a task which makes the utmost demands on the surgeon's skill.

MATERIAL AND METHODS

The present analysis comprises the results of 95 free tendon graftings performed in the Orthopaedic Hospital Aarhus during the period 1949-1965. These operations done on a total of 90 patients are equally distributed on the digits of the right and left hand. The distribution of the digits is shown in Table 1. The patients ranged in age between 7 and 67 years. 34 patients were younger than 15 and 6 were older than 50. The age distribution is listed in Table 2. On the basis of the manner of injury the operated digits may be divided into 3 groups: 31 digits with uncomplicated clean cuts and digits showing crush injuries and lacerations often with fractures, articular and nerve damage. Sequelae of previous tendon suture or tendon grafting must be assigned to the latter group.

The tendon grafting was carried out in 18 cases because of injury to the flexor pollicis longus in the tendon sheath and in 6 cases because of injury to both flexor tendons within the fibrous tendon sheaths of the fingers (Bunnell's "no man's land"). Only in one case was tendon grafting done because of an isolated injury to the flexor digitorum profundus preserving the flexor digitorum sublimis.

Preoperatively it was endeavoured to obtain a full passive mobility of the finger joints. Union of fractures was awaited, scar formations were corrected, skin grafting was done and in some cases nerve repair. 40 of the digits were operated upon within the first 4 months after the accident, only 4 more than 1 year after.

The operation was carried out in a bloodless field after disinfection by soap and water. The approach was mid lateral in about half the operations dorsal to and in

the other half volar to the nerve vessel bundle. In some cases this incision was combined with a transverse incision. In the palm the incisions were applied parallel to the natural creases. As a donor tendon we used the tendon of the extensor digitorum longus (pedis) in 62 cases, that of the plantaris longus in 4, and that of the palmaris longus in 28 cases. In one case it is not stated from where the donor tendon was taken. When the tendon of the extensor digitorum longus pedis was used its distal end was fastened to the tendon of the extensor digitorum brevis pedis.

Table 1 Distribution on the digits of the operations

	Thumb	2nd digit	3rd digit	4th digit	5th digit
Number of operations	18	20	30	13	14

Table 2 Age distribution of the patients

Age groups	0-9	10-19	20-29	30-39	40-49	50-59	60-69
Number of patients	18	33	18	8	7	4	2

The fixation of the tendon to the distal phalanx was done in 58 cases by suturing the tapered graft with 1 notted silk 0000 in a V shaped cut to the distal stump of the flexor digitorum profundus. In 37 cases the tendon was fastened to a hole drilled into the distal phalanx using pull out wire. Proximally the suture was performed as interlacing or fish mouth suture using silk 0000 (in a few cases wire). The suture line was covered with the lumbricalis muscle. When suturing to the flexor pollicis longus the suture line was applied as far proximally as possible but not always in the muscle. Prior to or during the operation 27 of the 81 injured nerves on the operated digits were repaired. In 7 cases nerve grafting was done. The suturing was done with silk 00000000. During the operation damaged pulleys were reconstructed. Pressure dressing was applied with a plaster cast, and the tendon was kept non functioning for 3 weeks. Pull out wires were removed at the end of 4 weeks and at the same time exercises were started. In some cases showing contractures an elastic traction splint was used for a varying length of time.

Follow up

Out of a total of 90 patients 72 were examined in their homes. About the others relevant data were found in the case records. ■ had gone abroad, † had died of irrelevant causes, one has undergone amputation, one had a stiff useless finger and ■ were not seen for other reasons. The follow up period was between 1 and 18 years except in 4 cases less than 1 year.

The function of the tendon is reflected in the excursions of the distal phalanx. If the extension defect of the distal phalanx ■ recorded as the sum total of the extension defects of the three joints and the flexion ability of the distal phalanx as the sum of the excursions in the three joints when the finger is flexed maximally.

Table 3

Tendon grafts in the fingers 77 cases	Age at operation	Lesion of digital nerve	Extension defect in the distal phalanx	Mobility of the distal phalanx	Mobility in the M I joint	Mobility in the proximal I P joint	Mobility in the distal I P joint	Flexion defect in distal phalanx
Age 2-15 years	14	1	normal					
uncomplicated cases	11	0	10	70	100	100	60	0
(clean cut)	11	2	20	260	100	100	50	■
	10	1	25	230	110	100	25	10
	7	1	5	230	■	100	40	30
	4	0	0	270	■	100	30	50
	9	0	0	190	100	60	20	80
	10	0	20	180	80	80	70	■
	15	2	70	180	90	80	10	70
	4	0	15	180	90	70	15	70
	4	0	30	180	■	60	30	60
	2	0	5	170	60	■	30	90
	14	2	55	160	90	60	10	50
	2	0	5	160	90	60	10	100
	4	0	90	130	90	50	10	20
	10	0	30	140	110	70	10	90
	2	0	0	170	90	20	5	130
	13	2	20	120	90	30	■	170
	10	0	amputated					
Age 2-15 years	7	0	normal					
complicated cases	15	1	0	220	100	90	30	30
	5	1	20	190	100	80	10	55
	7	0	40	140	100	50	15	60
	2	0	25	145	90	35	■	100
	2	0	60	155	90	20	40	50
	13	0	5	170	90	30	0	145
	5	2	80	100	60	30	5	■
	5	1	20	40	70	70	0	210
Age 16-49 years	■	1	10	240	110	70	60	70
uncomplicated cases	19	0	0	270	90	90	40	45
	24	1	0	215	110	80	25	55
	29	0	15	210	110	70	30	40
	19	0	30	210	90	90	20	30
	49	1	10	190	100	90	0	70
	20	1	30	171	80	90	1	69
	17	2	25	170	60	90	■	75

Table 3 (cont.)

Tendon grafts in the fingers 77 cases	Age at operation	Lesion of digital nerves	Extension defect in the distal phalanx	Mobility of the distal phalanx	Mobility in the M P joint	Mobility in the proximal I P joint	Mobility in the distal I P joint	Flexion defect in distal phalanx
	24	1	35	165	100	60	5	70
	27	1	115	140	120	10	10	15
	19	2	90	140	90	50	0	40
	49	1	5	135	85	40	10	130
	17	1	25	170	90	30	0	125
	22	2	90	115	100	15	0	65
	19	1	25	110	80	30	0	135
	27	1	130	110	90	20	0	30
	18	1	65	105	90	5	10	100
	16	2	170	100	90	5	5	0
	33	1	45	80	70	0	15	140
	22	1	30	80	80	0	0	160
	42	0	105	55	45	5	5	110
<hr/>								
Age 16-49 years complicated cases	19	1	20	180	110	70	0	70
	21	0	80	170	90	70	10	20
	28	0	2	170	90	80	0	98
	33	0	0	170	110	60	0	100
	40	2	70	160	90	65	5	40
	18	2	30	160	100	50	10	80
	19	2	20	165	80	70	5	90
	29	1	45	155	100	30	25	70
	31	2	20	150	90	60	0	100
	27	1	40	150	90	30	30	80
	29	1	40	150	70	70	10	70
	18	2	75	145	100	40	0	50
	31	0	70	140	80	40	10	55
	29	1	5	135	110	5	20	130
	19	0	35	125	70	50	0	110
	28	0	2	115	90	25	0	153
	25	2	30	95	90	0	5	145
	39	2	10	90	90	0	0	75
	40	0	45	90	90	0	0	130
	20	2	60	80	80	0	0	130
	22	2	70	70	45	10	15	130
	18		amputated					
	23		re-operated (tendon rupture)					

Table 3 (cont)

Tendon grafts in the fingers 77 cases	Age at operation	Lesion of digital nerves	Extension defect in the distal phalanx	Mobility of the distal phalanx	Mobility in the M P joint	Mobility in the proximal P joint	Mobility in the distal P joint	Flexion defect in distal phalanx
Age 50 and over uncomplicated	52	0	20	150	90	40	20	100
Age 50 and over complicated	50	0	70	140	90	55	0	100
	60	2	10	120	110	15	0	130
	66	1	20	90	80	10	0	160
Isolated injury to flexor digitorum profundus	25	2	30	200	90	90	20	35

with the wrist in a position of function the flexion defect of the distal phalanx may be calculated as 70° (normal mobility) subtracting (extension defect + flexion)

The results are listed in tables stating for each case the age at the time of operation and whether the tendon injury co existed with injury to 1 or 2 digital nerves. The individual cases are arranged according to the results obtained. The age groups 2-15 years 16-49 years and older than 50 years are listed separately and each age group is divided into 2 sub groups depending upon whether there was a case of a clean cut without complicating injuries or whether there was a crush injury and/or complicating injuries.

In recording the operated thumbs the table gives the total extension defect in the distal and proximal phalanges the excursion in the proximal joint and the excursion in the distal joint. In addition the latter is stated in degrees. Because of the difficulty in recording the mobility of the carpo metacarpal joint accurately in degrees the restriction of the spread of the interstice (measured from the tip of the thumb to the tip of the index finger—compared with the other hand) was measured and so was the distance from the pulp of the thumb to the base of the little finger during opposition.

RESULTS

In assessing the results for the 4 fingers Littler's criteria were used (excellent = 240 flexion + full extension good = 180). It was found that in the age group 2-15 years (clean cuts) there were 11/19 = 57 per cent good results in the same age group but with complicating injuries there were 3/9 = 33 per cent good results. In the age group 16-49 years (clean cuts) there were 6/21 = 27 per cent good results.

Table 4. *Tendon grafting to flexor pollicis longus (18 cases)*

	Age (years)	Lesion of digital nerve	Extension defect in proximal joint + extension defect in distal joint	Mobility in the distal joint in degrees	Mobility in the distal joint in degrees	Mobility in the proximal joint in degrees	Distance in cm from the pulp of the thumb to base of the little finger in opposition	Lack of full spread in the first interstice measured in cm
Uncomplicated cases	19	0	0	45	0/45	45	1	0
	5	0	-35	45	-15/30	25	1½	1½
	7	0	0	45	0/45	25	1½	1½
	13	0	20	70	20/90	70	0	1
	14	0	-10	0	-10/-10	45	1	0
	21	1	0	15	0/15	40	2	4
	19	1	0	45	0/45	60	0	4
	20	1	0	10	0/10	45	1½	0
	46	2	10	30	-20/10	15	3	0
	15	2	0	15	5/20	20	1½	3½
Complicated cases	39	2	-10	35	0/35	45	1	0
	10	2	0	45	0/45	35	1	0
	36	1	10	15	0/15	15	1	3½
	33	0	15	55	10/65	30	0	3
	19	0	0	20	0/20	20	3	3
	48	2	no active movement				5	1½
Age 60 years and over	52	1	0	35	0/35	35	1	0
	60	2	20	0	0/5	25	1	3½

and in the same age group with complicating injuries $1/23 = 4$ per cent good results. In the over 50 group there were a total of $0/4 = 0$ per cent good results. In the one case having grafting for an isolated injury to the flexor digitorum profundus the result was good. In the 18 cases treated by grafting to the flexor pollicis longus the results were in 3 cases better and in 4 cases equally good as if no operation had been performed; the remainder were poorer.

DISCUSSION

The operative results reported in the literature have been recorded partly by measuring the excursions in degrees and partly by measuring

the restriction of movement stated as the distance from the finger pulp to the distal crease of the hand and the distance from the finger nail to the level of the metacarpal bone in maximum flexion and maximum extension of the finger. At times the two methods have been combined. It is common to both modes of recording that they are suited rather for comparing the operative results in uniform materials than for affording a consistent characteristic of the individual material. Modes of recording which state the results in centimetres give too favourable results in cases of small hands with short fingers. A total excursion measured in degrees gives no information about the distribution of the mobility of the individual joints or about the site in the joint concerned in which the movement takes place. Both bear relation to finger function. Complete recording of these factors is difficult to survey both when tabulated and illustrated in diagrams.

Recording the mobility of the thumb in degrees involves the difficulty that it is hard to obtain an accurate measure of the excursion of the movement in the carpo-metacarpal joint. Many surgeons use the excursion in the distal joint as a measure of tendon function. However it is well known that the position in the proximal joint influences the extent of the excursion and moreover the thumb may often be extended in the proximal and distal joints while there is a decrease in the width of the first interspace in maximum extension and abduction in the carpo metacarpal joint. This factor is of importance to thumb function. In the present study therefore the author decided to record the decrease in the width of the first interspace while simultaneously recording the excursion of movements in the joints in degrees.

The results were most favourable in the group having clean cuts and better in the under 15 age group than in older patients. In patients over 50 years of age the results were poor. Tendon function does not appear to be dependent upon whether nerve injury is present in the operated finger and it could not be demonstrated that better results were obtained in some categories of fingers than in others. If operation is performed within the first months after the accident the operative results appear to be identical. One patient had the operation several years after the original trauma and the result was poor. Furthermore the importance of who performs the operation has been demonstrated. As Full bright lecturer the late American Professor H. Allen operated upon a number of patients of all preoperative categories with good results in two thirds.

In assessing the functional result however one should not rest con-

tent with paying regard to the isolated tendon function. As far as function is concerned, an extension defect and restricted width of the first interstice give rise to more complaints than does a flexion defect.

Moberg et al. have correctly pointed out the role of sensibility, and in particular tactile gnosis, in hand function. The patients often complain that a stiff finger is in the way, but the fact is that they are unable to orientate this finger unaided by vision. A finger which does not have full sensibility on the apposition surface is not used if another finger with normal sensibility is available. Only in one out of the 29 cases of nerve repair (in a child) did the sensibility prove near normal, with a 3-point discrimination of less than 4-5 mm, and even in this case the patient did not use the finger, an index finger, for precision grip. The remaining patients showed varying degrees of hypo- and dysaesthesia, somewhat better than in cases where the nerve had not been repaired. In all cases but one there was protective sensibility, both in cases where the nerve had been repaired and in others where it had not. In 4 of the cases treated by pulley reconstruction the pulley had given way, leaving the tendon like a sail on the volar aspect of the finger.

Actual operative complications were observed partly in connection with the operation proper and partly in removing suited donor tendons. In the former group there were 3 cases of taut volar scars, 2 cases of injury to functioning finger nerve, 1 case of injury to the ulnar nerve (pressure by a Pean forceps) and in 1 case posttraumatic dystrophy. In addition there was a case of granuloma on the finger pulp left by a pull-out wire and a cleft thumb nail after drilling of the tendon into the distal phalanx.

The complications in removing donor tendons comprise 3 cases of annoying drop toe, 4 cases of annoying paraesthesiae on the foot through many years, 2 cases of transient paraesthesiae in the area innervated by the median nerve and one case of neuroma affecting the cutaneous branch of the radial nerve.

It is evident from the above that our results are poorer than they ought to have been. In the literature there are reports of up to 90 per cent good results in the best risk categories. The surgeons have been experienced, the technique has been the current one in hand surgery at the time of the operation, and physiotherapists, ergotherapists, as well as an up-to-date bandage workshop have been available.

In 1950 *Boyes* published a material of free tendon grafts divided into groups of about 25 treated in each year. This analysis showed that of the patients from the first year less than 50 per cent could flex up to

1½ inches from the distal crease of the hand and that 2 operations were complete failures while among the patients from the last year of analysis 86 per cent had the above mentioned function. This result was attained without any change in technique except that the surgeon had acquired greater skill.

With the number of free tendon graftings indicated every year in this country each hospital will have only a very few cases.

In Ugeskrift for Læger No 35 1967 it is concluded in an editorial that nerve repair must be considered a task for specialists and that this will be even further accentuated by the constant advances in suturing technique.

The present analysis supports the view that free tendon grafting just like nerve repair must be considered a task for specialists which ought to be centralized in a few departments. Only in this way is it possible to acquire and maintain the experience and routine necessary to obtain good results.

SUMMARY

The results of 93 free tendon graftings are reported. 18 were to the flexor pollicis longus. 76 were done in injuries to the flexor digitorum profundus and sublimis and one in the case of an isolated injury to the flexor digitorum profundus in the tendon sheath. By the criteria of Littler there were 57 per cent good results in uncomplicated cases (clean cuts) and 33 per cent in complicated cases in the age group 2-15 years. The corresponding values in the age group 16-49 years were 27 per cent and 4 per cent respectively. In the over 50 group the values were 0 out of 4. Among 18 cases of grafting to the flexor pollicis longus the function of the thumb had all considered improved in 7. The mode of recording and the role of complicating injuries in the functional result are discussed. Operative complications of importance occurred in 10/93. The surgeon's share in the operative result is established.

It is concluded that free tendon grafting is a task for specialists which ought to be centralized in special departments.

RÉSUMÉ

Les résultats de 93 greffes libres de tendons sont rapportés. 18 ont été pratiqués pour le long fléchisseur du pouce. 76 à la suite de lésion du fléchisseur profond les doigts et un dans le cas d'une lésion isolée du fléchisseur profond les doigts dans la gaine du tendon. 0 après les

criteres de Littler, les resultats ont ete bons dans 57 pour cent des cas sans complications (coupe nette) et dans 33 pour cent des cas compliques dans le groupe d'age de 2 a 15 ans. Les donnees correspondantes dans le groupe d'age entre 16 et 49 ans ont ete respectivement 27 et 4 pour cent. Dans le groupe des personnes de plus de 50 ans les donnees ont ete 0 sur 4 cas. Parmi 18 cas de greffes du long fléchisseur du pouce la fonction a ete ameliorée chez 7 malades tout pris en consideration. Il est discute du mode d'observation et du role des lesions compliquees pour le resultat fonctionnel. Des complications operatoires importantes ont ete observees dans 16 des 95 cas. La question de l'habilete du chirurgien pour le resultat operatoire est etablie.

Il est conclu que la greffe libre des tendons doit etre realisee par des specialistes que l'on devrait centraliser dans des services speciaux.

ZUSAMMENFASSUNG

Die Ergebnisse von 95 freien Sehnentransplantationen werden berichtet. 18 wurden am Flexor pollicis longus, 76 bei Beschädigung des Flexor digitorum profundus und sublimis und eine bei einer isolierten Beschädigung des Flexor digitorum profundus in der Sehnenscheide vorgenommen. Gemäss der Beurteilung nach Littler wurden 57 Prozent gute Resultate bei den unkomplizierten Fällen (reine Schnittwunden) und 33 Prozent bei komplizierten Fällen in der Altersgruppe 2-15 Jahre erhalten. Die entsprechenden Werte in der Altersgruppe 16-49 Jahre waren 27 Prozent beziehungsweise 4 Prozent. In der Gruppe über 50 Jahre waren die Werte 0 bei 4 Patienten. Von 18 Fällen mit Transplantation zum Flexor pollicis longus war die Funktion des Daumens in 7 gebessert. Die Art der Darstellung und die Rolle von komplizierenden Schäden auf das funktionelle Endresultat werden besprochen. Operative Komplikation von Wichtigkeit traten in 16/95 Fällen auf. Der Anteil des Chirurgen in den operativen Ergebnissen wird festgestellt.

Man schliesst, dass freie Sehnenverpflanzung eine Aufgabe für Spezialisten ist, die in besonderen Abteilungen zentralisiert sein sollte.

REFERENCES

1. Boyes J.H. M.D. (1950) Flexor tendon grafts in the fingers and thumb. *J. Bone Jt. Surg.* 32 A: 499-499.
2. Weckesser Elden C. M.D. Evaluation of results of tendon repair (References). Flynn J. Edward. *Hand Surgery*. Williams & Wilkins, Baltimore 1966.
3. Editorial (1967) *Ugeskr. Læg.* 35.

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OSTEOTOMY IN DEGENERATIVE AND RHEUMATOID ARTHRITIS OF THE KNEE JOINT

By

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INTRODUCTION

Osteotomy in the region of the knee joint has been described for about a century. Only during the last ten years though have significant reports appeared on its use for degenerative arthritis and less often for rheumatoid arthritis. This recent development signifies a different aim for the operation. The older aim was essentially the correction of static deformities including valgus varus or recurvatum or the correction of flexion contractures of functionally significant degree. The aim in the treatment of rheumatoid and degenerative arthritis encompasses positional improvement of course but relief of pain is also hoped for and alteration of mechanics and of bone circulatory pattern so that a continuing disease process in the knee joint will be retarded, arrested or to some degree turned back.

A clinical Lecture on Antiseptic Osteotomy by Macewen appeared in *Lancet* in 1878 (Steindler 1940). From the textbook by Jones & Lovett (1924) it appears that at the turn of the century osteoclasis was still accepted particularly in children as well as forceful closed distal femoral epiphysiostasis. Of the latter the authors say: "In unskilled hands it is definitely dangerous." Osteotomy through limited incisions or by means of driving a chisel straight in through the skin is also described here. For arthrosis deformans debridement or arthrodesis is described and osteotomy is not mentioned.

Osgood in 1913 published a report of brief experience with supracondylar femoral osteotomy for permanent knee flexion contracture. Wedge removal was performed and either a green stick or complete fracture of the posterior cortex made. Milch in 1934 also favored

osteotomy leaving one cortex unosteotomized. He emphasized that in unsuccessful supracondylar femoral osteotomy one cause is that the original angular deformity is not corrected but only compensated. He also emphasized that in osteotomy one must make certain that the upper and lower tibial articular surfaces are parallel to each other and perpendicular to the shaft.

Many types of osteotomies have been described with or without wedge removal or wedge addition (*Agerholm 1960 Smilie 1962 Chimesco & Antonesco 1964*). Simple linear osteotomy with angular displacement has been used in degenerative arthritis (*Wardle 1962 1964*) as has the ball and socket type (*Jackson & Waugh 1961*). The osteotomies applicable to the subject of this paper are wedge osteotomies (*Torgerson 1965 Gothefors & Hult 1964 Coventry 1965*) or those of the telescoping type.

MATERIAL AND METHODS

Patients with rheumatoid or degenerative arthritis of the knee joint who during the ten years from 1956-1965 were subjected to osteotomy of the distal femur or proximal tibia at the Orthopaedic Department of Malmö General Hospital have been re-examined. Twenty-eight knees were operated in twenty-eight patients. Six of the patients had died before the time of the final follow-up examination. The result of operation in these six cases was evaluated through study of the X-rays and the clinical record. The rest of the patients came for examination and were evaluated clinically and roentgenographically. Follow-up time varies between one and ten years with a median time of four and one-half years. Eleven patients had rheumatoid arthritis and seventeen degenerative arthritis (Table 1). The median age at operation was 63.7 years with the oldest 76 and youngest 50. The age breakdown is shown in Table 2.

Table 1 Material

	Male	Female
Rheumatoid arthritis	2	9
Degenerative arthritis	6	11

Table 2 Age breakdown

	50-59	60-69	>69
Rheumatoid arthritis	4	5	2
Degenerative arthritis	7	2	8

Table 3 Deformity

	Valgus	Varus	Extension defect
Rheumatoid arthritis	8	2	1
Degenerative arthritis	7	10	11

Table 4 Osteotomy site

	Tibia	Femur
Rheumatoid arthritis	2	9
Degenerative arthritis	10	7

Table 5 Results

	Improved	Unimproved	Not evaluated
Rheumatoid arthritis	2	8	1
Degenerated arthritis	10	7	

In fifteen cases the deformity consisted of valgus deformity in twelve of varus and in one of a fixed extension defect. In two cases varus or valgus correction were performed together with correction of an extension defect (Table 3). Valgus deformity was most common in rheumatoid arthritis; varus in degenerative arthritis. The surgery was performed by a number of different surgeons and the technique varied. Twelve of the osteotomies were in the proximal tibia and sixteen in the distal femur (Table 4).

RESULTS

The results have been divided into two groups: improved and unimproved. In the first group are patients whose pain was gone or clearly decreased and whose walking ability was significantly improved. All other patients were judged as unimproved. Ten of the seventeen patients with degenerative arthritis were improved and only two of eleven patients with rheumatoid arthritis (Table 5). One patient died of pulmonary tuberculosis three months after surgery and so could not be evaluated. The other five patients who died died between six months and six years after operation. Three of the six patients who died had rheumatoid arthritis, three degenerative arthritis. All of the patients that died were over 67 years (average 72.2).

Local complications occurred in six cases. In three cases dislocation of the osteotomy occurred and in one of them re-operation with internal fixation was needed. All of these three were in telescoping supracondylar femoral osteotomies without internal fixation. Three pseudarthroses occurred requiring re-operation: one in the distal femur, two in the proximal tibia.

The range of flexion in the knee joint was only in four cases less than 90° where it was 90° or more pre-operatively. These four had significantly decreased motion after operation. Three of them were supracondylar and one proximal tibial osteotomies. In two of the cases pseudarthrosis had occurred and in one postoperative dislocation

of the fragments. In one case synovectomy was performed at the same time as supracondylar femoral osteotomy.

DISCUSSION

Improvement after surgery has taken place in fewer than half of our cases. The patients with rheumatoid arthritis have noticeably responded poorly to osteotomy. The patients evaluated as improved have however shown a very significant improvement. Other authors have presented good results in many cases (Table 6). Choice of indications for osteotomy and of surgical technique are of considerable significance in obtaining good results, and through uniformity and discrimination in these factors the value of osteotomy should increase considerably.

Osteotomy in rheumatoids is only sparsely described in the literature (Coventry 1965). Of the eleven cases in our series only two showed significant improvement. These patients had symptoms chiefly localized to a knee joint with pronounced deformity, while the other joints were rather well preserved and the patients' general condition was good. The remaining patients in this group were severely incapacitated in several joints, and the operated knee showed pronounced destruction preoperatively. When surgery is planned in these advanced cases arthrodesis should be strongly considered. In a few cases synovectomy was performed together with osteotomy. These patients became pain free, but motion was severely limited. It does not seem advisable to carry out these operations together, because osteotomy demands a period of immobilization, while early mobilization is desirable after synovectomy. In one case surgery produced improved walking and weight bearing ability on the operated extremity, which led to rapid destruction with central dislocation of the already disease destroyed hip joint. The hip joint requires special evaluation before considering knee osteotomy. Of special significance are abduction and adduction ability, because correction of valgus or varus deformity results in an altered axis in the hip joint with walking.

The results of osteotomy in degenerative arthritis were better than in the group with rheumatoid arthritis. In the cases which did not improve, the cause was pronounced destruction preoperatively in the operated knee, co-existing difficulty with other joints (hip, ankle) or complications in the form of delayed union or dislocation of the osteotomy. The cases suitable for surgery are those with significant

valgus or varus deformity with destructive changes and symptoms from the concave side of the joint and in which the range of motion is at least 60-70°

The surgical technique varied in our cases. The determining factor for whether distal femur or proximal tibia osteotomy was chosen was the joint surface. The surfaces of the ankle joint and knee joint should be parallel (Figure 1). In tibial osteotomies done more recently a wedge was removed proximal to the tibial tuberosity and fixation was achieved with staples (Figure 2). Good fixation was obtained in this way and plaster fixation was required for only about four weeks after which joint motion training was possible. In the two cases with pseudarthrosis of the tibia osteotomy was distal to the tuberosity and internal fixation was not used.

Most of the distal femoral osteotomies were of the so-called telescoping type (Figures 3 and 4). Dislocation took place postoperatively in three and pseudarthrosis in one. This high complication rate can be explained by technical errors. It is very important that the osteotomy be made sufficiently distally so that the tip of the shaft fragment is located immediately above the broadest portion of the condylar flare. The point is located on the deformities convex side. On the concave side a cortical bridge of about 2 centimeters width is preserved and not osteotomized. This bridge is broken as the deformity is corrected by means of pressing the point of the shaft fragment into the condylar fragment. In this way the position is so stable that internal fixation is not required. A plaster from groin to toes is applied.

The benefit from osteotomy in the knee region that is due to correction of distorted weight bearing and thus to correction of excess lo-

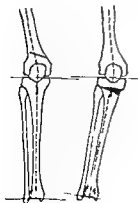


Figure 1 Level of osteotomy when the deformity is situated above the knee (A) and below the knee (B)



Figure 2 X-ray of a wedge osteotomy of the proximal tibia

Figure 3 Schematic drawing of supracondylar femoral osteotomy of the telescoping type



Figure 4 X-rays of a supracondylar femoral osteotomy of the telescoping type

calized compression and of instability needs no further explanation. It has further been suggested that pain relief is due to relief of intramedullary venous pressure (Wardle 1964), improvement in the nutrition of the articular cartilage (Smillie 1962) and alteration of the vascular network (Trueta 1962). The comments regarding vascular improvement are similar to those made about proximal femoral osteotomy for degenerative arthritis of the hip and similarly one finds reports of steadily improving knee cartilage space and reversal of roentgenological signs of subchondral changes (Jackson & Waugh 1961, Wardle 1962, 1964). Whichever explanations are ultimately accepted the operation seems of great value when done with the proper indications and surgical technique.

Author	X ray improvement	
Jackson &	ed	Joint sclerosis decreased in 2 cases 1 $\frac{1}{2}$ and 3 $\frac{1}{2}$ years after operation
Wardle	in 14 cases	Cysts improve time not specified
Wardle	least 90 by	Joint space increases over 5 years
Veenemans	ed	No changes occur Time not specified
Gothefors	d	"
Coventry	with full extension in 18	Not specified

REFERENCES

- Ågerholm J (1966) The zig zag osteotomy *Acta orthop scand* 28 62
- Climensco V & Antonesco D (1964) Losifotomie à coin dans le traitement des déformations du genou *Acta orthop belg* 30 438
- Coventry M H (1965) Osteotomy of upper portion of tibia for degenerative arthritis of knee *J Bone Jt Surg* 47 A 984
- Göthefors L & Hult L (1964) Resultat efter osteotomi vid gonarthros *Nord Med* 72 1402
- Jackson J P & Waugh W W (1961) Tibial osteotomy for osteoarthritis of the knee *J Bone Jt Surg* 43 B 746
- Jones H & Lowell R W (1924) Orthopaedic surgery William Wood & Co New York
- Macewen W (1878) Clinical lecture on antiseptic osteotomy *Lancet* 1 449 (cited by Steindler 1940)
- Milch H (1934) Juxta articular partial tibial osteotomy *Surg Gynec Obstet* 59 87
- Osgood R B (1913) A method of osteotomy of the lower end of the femur in cases of permanent flexion of the knee joint *Amer J orthop Surg* 11 336
- Smillie I S (1962) Injuries of the knee joint E & S Livingstone Ltd Edinburgh
- Steindler A (1940) Orthopaedic operations indications technique and end results Charles C Thomas Springfield Ill
- Torgerson W R (1965) Tibial osteotomy in the treatment of osteoarthritis of the knee *Surg Clin N Amer* 45 779
- Trueta J (1962) Tibial osteotomy for osteoarthritis of the knee In Proceedings and reports of councils and associations *J Bone Jt Surg* 44 B 906
- Wardle E N (1962) Osteotomy of the tibia and fibula *Surg Gynec Obstet* 115 61
- Wardle E N (1964) Osteotomy of the tibia and fibula in the treatment of chronic osteoarthritis of the knee *Postgrad med J* 40 536
- Veenemans C I (1963) Osteotomy of the upper tibial shaft. In Proceedings and reports of councils and associations *J Bone Jt Surg* 45 B 432

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CONGENITAL ANGULATION OF THE LOWER LEG

Crus Curvatum Congenitum

By

A SLOU ANDERSEN II BOHR & O SVEPPEN

Received 20 11 67

Congenital angulation of the lower limbs makes up a rare and ill defined syndrome which may be the precursor of so-called congenital pseudarthrosis of the tibia

Since *Camurati*, in 1930 published his report on these conditions there has been an increasing number of reports but the designations have differed e.g. intrauterine fracture crus varum congenitum congenital bent tibia congenital angulation of tibia the¹kyphoscoliotic tibia and congenital pseudarthrosis of the tibia

Since the aetiology of these congenital angulations is unknown the syndrome is only a clinical concept maintained chiefly because of the risk of pseudarthrosis

Israelich (1910) stated that this pseudarthrosis was not always congenital but often resulted from fracture of the lower leg which had been bowed from birth According to *Kosic* (1941) pseudarthrosis developed only in anterolaterally convex legs his term referring to the entire condition was crus varum congenitum Other directions of angulation are more uncommon but may also give rise to pseudarthrosis (*Camurati* 1930)

Büttner & Eysholdt (1950) do not feel that it is possible to decide with certainty whether all congenital angulations of the lower leg make up a pathogenetic entity According to *Lindemann* (1961) there is not however much doubt that intrauterine fracture crus varum congenitum and the congenital pseudarthroses of the tibia are pathogenetically closely related

At our present stage of knowledge it seems reasonable to collect all

cases of congenital angulations of the lower leg under one common designation

Landemann in 1961 suggested the term *crus curvatum congenitum* (c c c) meaning all congenital angular deformities of the lower leg in so far as the more systemic diseases of bone could be ruled out. This term will be used here.

Interpreted in this way c c c makes up a characteristic syndrome. It is most often unilateral although bilateral cases have been reported e.g. by Camuratz (1930) and Ducroquet & Cottard (1939). The angulation is present at birth or appears within the first days of life. It nearly always affects the distal half of the lower leg, the most characteristic site being at the junction of the middle and distal third. Radiography often shows thickening of the cortex on the concave aspect of the bone on a level with the apex of the angulation. At times there are cystic changes or fracture of the bone at the site of the angulation. While these changes are invariably present in the tibia, the fibula may be radiologically normal. As a rule, however, it shows the same changes as the tibia. In certain cases the fibula may be absent and these cases have sometimes been classified in a separate group (Farmer 1960). Since they are accompanied in the majority of cases by angulation of the tibia and since pseudarthrosis has been described in this group too (Aitken 1959) it seems reasonable to assign them to c c c.

Previously most interest was devoted to the aetiology and treatment of the congenital pseudarthroses of the tibia. We felt that it must be of interest to elucidate the prognosis of c c c with a view to spontaneous correction of the angulation and to the risk of pseudarthrosis.

MATERIAL

During the period 1934-1966 a total of 40 cases of c c c were treated in the Orthopaedic Hospital, Copenhagen.

Twenty patients were seen in the hospital for the first time within the first 8 weeks of life and only 11 patients were over one year of age when first seen. In all cases the angulation had been present at birth.

The follow up period ranges from 6 months to 32 years, average 13.5 years. When the analysis was completed about new year 1966-1967 6 patients were under 5 years of age while 8 were from 5 to 10 years, 7 from 11 to 15 years and 19 were over 15 years of age.

The sex distribution is given in Table 1. There was only one bilateral case and of the remaining 39 cases 20 were right sided and 19 left sided.

To divide the cases of c c c into subgroups as uniform as possible from the

Table 1 Distribution of *Crus curvatum congenitum* by sex and type of angulation

Sex	Type of angulation		
	Anterior with associated congenital deformities	Anterior without associated congenital deformities	Posterior
Female	5	7	6
Male	16	3	3
Total	21	10	9

prognostic point of view we felt that it would be expedient, as done by Heymann (1949) to distinguish between cases with anterior angulation without associated congenital deformities cases with anterior angulation with associated congenital deformities and cases with posterior angulation

The angulation of the antecurved legs was most often antero lateral convex or purely anteroconvex. In the group without other associated deformities all 10 cases were antero laterally convex. In the group with associated deformities the angulation was in 4 cases antero laterally convex in 10 cases purely anteroconvex. In 4 cases the angulation was antero medially convex.

Of the cases with posterior angulation 8 were postero medially convex and one postero convex.

Patients with ccc often have other congenital deformities. Among the 40 cases of ccc there were 29 with hypoplasia of the ipsilateral lower limb 19 had congenital deformity of the ipsilateral foot 6 had dimpling of the skin and 8 had a congenital constriction at the site of the angulation. In 17 cases there was aplasia of the ipsilateral fibula and in 3 syndactyly of fingers.

Out of the 31 cases with anterior angulation 6 had a congenital constriction and 5 dimples in the skin. In 12 there was aplasia of the fibula. In 8 of these latter cases there was also absence of either the 5th or the 4th ray in the foot. 6 patients had congenital equino valgus foot one congenital equino varus. In 2 cases there was such pronounced hypoplasia of the foot that it presented merely as a lump without definite ossification.

Out of the 9 cases with posterior angulation 2 had associated congenital constrictions 1 had dimpling of the skin 1 had calcaneo valgus and 1 pronounced hypoplasia of the foot without ossification.

Two factors are of essential importance to the functional ability obtainable in ccc. One is the degree of hypoplasia and the attendant shortening and the other is the occurrence of fractures and their tendency to unite.

Hypoplasia is present in varying degree in ccc. Among 17 cases seen at birth or shortly after 7 had mild hypoplasia with up to 1 cm shortening of the lower leg 6 had 2-3 cm shortening and 4 more than 4 cm shortening.

Hypoplasia occurred in legs with anterior as well as posterior angulation. Out of 11 patients with anterior angulation 20 exhibited considerable hypoplasia and shortening. And among these 11 cases the hypoplasia was so marked in 8 that in combination with a deformed foot it made up an indication for amputation. In 3 cases epiphysodesis of the contralateral leg had to be performed.



Figure 1 a + b OH 983/67 The spontaneous correction in a *Crus curvatum congenitum* with posterior angulation a) at the beginning of follow up b) 4 years later

Out of 9 patients with posterior angulation 8 had hypoplasia of major degree. Five required epiphysiodesis and one patient was fitted with a Syme prosthesis.

The tendency for the angulation to become spontaneously corrected was assessed by measuring the angulation in X-ray films from the beginning and from the end of the follow up period. In this connection it should be mentioned that the material is derived from a period of more than 30 years and therefore the therapeutic principles in respect to correcting the angulation have not been uniform throughout. A number of cases had been treated by corrective casts while others had had osteotomy or therapeutic fracturing.

In the 9 patients with posterior angulation primary examination showed angulation in the sagittal plane ranging from 105° to 170° average 150°. In 2 cases the bone was fractured at an early stage of the follow up period in an attempt to correct the angulation. The others have been followed for 4–19 years. At the end of the follow up period 6 of these patients showed satisfactory appearances (less than 10° angulation). In one case the angulation exceeded 10° but this patient had been followed for only 4 years during which spontaneous correction from 105° to 160° had occurred (Figure 1).

In the 31 cases with anterior angulation the angulation was 90–170° at the primary examination. After a short follow up period osteotomy was done in 3 cases and fracturing of the lower leg in one in an attempt of correction. In 2 cases the follow up period had been only 6 months so that it is not possible to assess the tendency to correction. In the remaining 8 cases the follow up period ranged from 4–27 years. Four obtained a satisfactory appearance with an angulation of less than 10°. In 4 cases the angulation exceeded 10° at the end of the follow up period.

The most serious complication of c.c.c. is fracture and pseudarthrosis. The fracture may be present at birth or it may occur within the first years of life. Our material includes 3 cases in which fracture was diagnosed immediately after birth. In 3 fracture occurred within the first year of life and in 6 within the 2nd–5th year of life. In another 3 cases therapeutic fracturing was done a few weeks after birth.

This gives a total of 13 fractures among the 40 cases of c.c.c. Out of these fractures 11 developed into pseudarthroses.

Out of the 3 fractures present at birth one developed into pseudarthrosis. Out of the 9 fractures occurring after birth all ended as pseudarthroses. One of the 3 therapeutic fractures developed into pseudarthrosis (Table 2).

Table 2. Cases with fracture and pseudarthrosis by type of curvature

	Type of angulation		
	Anterior with associated congenital deformities	Anterior without associated congenital deformities	Posterior
Total number of cases	21	10	9
Number of cases with fracture	3	10	2
Number of cases with pseudarthrosis	1	10	0

Corrective osteotomy was carried out in 4 cases—three with anterior angulation with associated deformities and one with posterior angulation. In all 4 cases the osteotomy healed within the normal time.

Some authors *e.g.* Moore (1949) and Badgley (1952) feel that on the basis of the X ray films they can pick out the prognostically unfavourable types claiming that thickening of the cortex on the concave aspect of the angulation with consequent partial or complete obliteration of the medullary canal predisposes to pseudarthrosis. However Exner (1959) and Mat en (1955) are sceptical of the pathogenic significance of this X ray finding.

Thickening of the cortex on the concave aspect of the bone was present in 26 of our cases. Partial obliteration of the medullary canal was found in 13, 8 of whom had complete obliteration. Only 3 of these 8 patients developed pseudarthrosis.

Cystic changes at the site of the angulation have often been reported. Compere (1936) published a case in which he believed the pseudarthrosis to be due to localized osteitis fibrosa. Green & Rado (1943) who also found cystic changes



Figure 2 Case of *Crus curvatum congenitum* with anterior angulation and development of fracture in a cystic tibia within 4 months

claimed that these were intraosseous neurofibromas. However, this claim has not been confirmed (Boyd 1958). In 4 of our cases the first X-rays showed cysts in the tibia. All later developed pseudarthrosis (Figure 2).

The angulation of the lower leg in the sagittal plane ranged from 90° to 170°. The magnitude of the angulation, measured as the numerical degree, could not be correlated to the risk of developing pseudarthrosis. Among 9 cases with an angulation below 140°, no pseudarthroses occurred. Among 21 cases with an angulation of between 140° and 180°, there were 4 cases of pseudarthrosis.

Pathological studies of congenital tibial pseudarthroses have been described by Camurati (1930). His studies as well as numerous subsequent ones have shown that histologically the congenital pseudarthroses do not differ from other pseudarthroses. Green & Rudo (1943) were the first to study a biopsy from a c.c.c. before fracture and pseudarthrosis occurred. This examination also failed to demonstrate specific histological features. In our material, biopsies from the site of pseudarthrosis were moved for microscopic examination in 4 cases subjected to operation for the pseudarthrosis, but no notable findings were made. In 4 cases, microradiographic study of the biopsies was done, and in 2 cases double labelling with tetracycline was done before removing the biopsies. These investigations did not reveal any special features of the bony structure, but in one case it seemed as if the rate of deposition of bone occurred faster than might be expected according to the patient's age (Figure 3).

DISCUSSION

The aetiology of c.c.c. is unknown. However, there is presumably a relationship between congenital pseudarthrosis of the tibia and von Recklinghausen's neurofibromatosis, as demonstrated by McIntosh Barber (1939) and Ducroquet & Cottard (1939). One case of neurofibromatosis occurred in our series, and this patient developed pseudarthrosis.

On the basis of the numerous theories advanced, Guilleminet (1953) suggested a working hypothesis presupposing that the congenital



Figure 3 Section through the bone near the pseudarthrosis labelled with Tetracycline OH 476/60

pseudarthroses of the tibia have invariably been preceded by segmental dysplasia or dystrophy. This dysplasia may be due to systemic causes such as mesenchymal damage, neurofibromatosis, endocrine disturbances, or to local causes such as a reduced blood flow through the part or intrauterine mechanical factors. This hypothesis comprises all known aetiological factors and seems to be at present the most acceptable one. Whether it can also embrace all cases of c. c. c. is not clear.

Clinically a distinction may be made between several types of c. c. c. Like *Badgley* (1952) we found cases with anterior angulation to be most common. In *Badgley's* series as well as in ours they constituted about 75 per cent. Cases with posterior angulation made up about 25 per cent. Both types are equally often associated with other congenital deformities, viz. in about one third.

From the prognostic point of view the three groups—anterior angulation without associated congenital deformities, anterior angulation with associated congenital deformities, and posterior angulation—are fairly sharply separated. Fractures ending in pseudarthrosis were by far most common in the group with anterior angulation without associated deformities. In *Badgley's* series this occurred in 1 out of 4 cases, and in our series in all 10 cases.

In the group with anterior angulation with other congenital deformities *Badgley* found 1 pseudarthrosis among 10, and we had 1 among 21.

In the group with posterior angulation *Badgley* had no pseudar-

throsis among 5 cases and in our series too there was none among 11 cases

Several workers have published cases in which the posterior angulation has become spontaneously corrected *Heymann* (1949) as well as *Lindemann* (1961) stated that cases with posterior angulation differ clearly from the cases with anterior angulation partly in respect to spontaneous correction and partly in respect to the risk of pseudarthrosis. In our material some spontaneous correction occurred not only in the group with posterior but also in that with anterior angulation. Probably the correction was more marked among the patients with posterior angulation.

Like several others before us, we have found no reason to presume that radiological findings such as thickening of the cortex and partial obliteration of the medullary canal are of any independent prognostic importance. On the other hand we have found cysts to be a serious prognostic sign predisposing to pseudarthrosis. This observation too is in accordance with those of previous authors.

In further accordance with previous findings (int al *Heymann* 1949 *Thyge Madsen* 1956) we found dimpling of the skin and a congenital constriction at the site of the angulation to occur in anterior as well as posterior angulations. We found no evidence for assuming that c c c with a congenital constriction or c c c with dimpling of the skin make up separate groups in respect to the risk of developing pseudarthrosis.

Cases showing aplasia of the fibula have been set apart by some workers as a separate group differing from c c c presumably wrongly. In our series no case of pseudarthrosis occurred in the group having c c c as well as aplasia of the fibula.

CONCLUSION

Cases of ■ c c with anterior angulation without associated congenital deformities very often develop pseudarthrosis. The therapeutic principle must be to avoid fracture. No weight bearing should be allowed and any kind of osteotomy is contra indicated. Repeated radiographic examinations should be done to detect cyst formation if any as this must be interpreted as a serious prognostic sign.

Cases of c c c with anterior angulation and other congenital deformities seldom end in pseudarthrosis. In these cases deformities of the feet and hypoplasia call for treatment. Presumably the leg should

not be braced as in this group the hypoplasia is frequently a problem. Correcting osteotomy should only be performed on strict indications.

Cases of $\equiv c c$ with posterior angulation very seldom develop pseudarthrosis. In these cases treatment is often required for foot deformities and hypoplasia. Presumably bracing of the leg is unnecessary. Osteotomy is rarely indicated. The prognosis is on the whole favourable.

SUMMARY

From 1934 to 1966 a total of 40 cases of congenital angulation of the lower leg here called *crus curvatum congenitum* ($c c c$) were treated in the Orthopaedic Hospital, Copenhagen.

The follow up period ranges from 6 months to 32 years.

$C c c$ is sometimes associated with other congenital deformities. About three quarters of all the cases were anterior and one-quarter posterior angulations. Associated congenital deformities were equally common in these two groups. Hypoplasia was present in varying degrees.

Fractures of the leg occurred in 15 cases. Out of 10 cases of $c c c$ with anterior angulation without associated deformities all had fractures with development of pseudarthrosis.

Assessment of the X-ray films appears to show cysts to be a serious prognostic sign in respect to pseudarthrosis: all our 4 cases with cysts developing pseudarthrosis.

An attempt to assess the tendency to spontaneous correction of the angulation showed that possibly this is most marked among the cases of posterior angulation.

The principle of treatment must be to avoid fracture as far as at all possible. In cases with associated congenital deformities treatment of foot deformities and hypoplasia is often required.

RÉSUMÉ

De 1934 à 1966 on a traité à l'Hôpital Orthopédique de Copenhague 40 cas d'incurvation congénitale de la jambe (*Crus curvatum congenitum* = $C c c$).

La durée des observations varient entre six mois et 32 ans.

La $C c c$ est souvent accompagnée d'autres déformités congénitales. 3/4 des malades étaient des cas d'antéincurvation et 1/4 de rétroincurvation. La fréquence d'autres déformités congénitales est la même pour les deux groupes. De l'hypoplasie a été observée à des degrés variables.

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DISAPPEARING BONE DISEASE, MORBUS GORHAM

Report of a Case

By

GUNNAR TILLING & BOHDAN SKOROWYTSKI

Received 21 v 67

Disappearing bone disease Morbus Gorham haemangiomatosis lymphangiomatosis massive osteolysis spontaneous absorption of bone phantom bone primary lymphangioma and crypto-genetic progressive localized osteolysis are various names for the same skeletal disease

The disease is characterised by osteolysis with bone disappearance and histologically pictures occur which are best interpreted as angiomas sometimes described as haemangiomatosis sometimes as lymphangiomatosis

The disease may affect only one bone but very often several adjacent bones are involved Histologically the picture is benign Malignant pathological tissue has never been observed Metastases have never been seen Deaths from the disease have been reported but then the process was localised to the rib bones or vertebrae and fatal complications arose owing to involvement of the pleura and the spinal canal (4 9 10 11 17) As a rule the disease makes slow irregular local progress The osteolysis may however cease as inexplicably as it began No regeneration of the vanished bone has ever been observed Generally the process does not confine itself to one bone but attacks skeletal parts Spontaneous fractures are common The osteolysis often commences at a young age Boys and girls are affected about equally

Disappearing bone disease is not accompanied by general symptoms No endocrinal disturbance is present nor any apparent chemical blood changes except during acute phases when the alkaline phosphatases may show a moderate increase

The disease may affect all skeletal parts Only a few cases are reported involving the skull (12 21)

The diagnosis is made with the aid of radiology and biopsy. Considerable surprise is experienced when this disease is seen for the first time for there is very little discussion of it in current textbooks.

Arteriography has not been of any diagnostic aid but possibly an intrasosseous injection of contrast medium may be of some use as the contrast medium is mainly collected in the angiomatous tissue. However no idea of the drainage conditions were obtained.

The earliest known publication is that of *Jackson* 1838 (13). His casereport concerned a man whose humerus underwent complete osteolysis. During the lengthy course of the disease he experienced repeated spontaneous fractures.

In 1905 *Gorham & Stout* described 2 cases of their own and compared the cases from previous publications a total of 24 cases. They emphasized the haemangiomatous tissue in the bone in the osteolysis zones. In 1906 (8) *Falkmer & Tilling* described a case of osteolysis in the lower region of the spine and adjacent parts of the pelvis in a man aged 50 where the histological picture showed lymphangioma in the osteolysis zones. No progress was seen in this case. At an X-ray examination in 1966 the condition was unchanged.

After the publications of Gorham and his colleagues (7, 8 & 20) more new cases have been published and the total number of cases now known approaches 100.

As we have observed another case of the disease we consider this worthy of publication.

CASE HISTORY

The patient was a girl born in 1904. There was nothing of interest hereditarily. At the age of 3 the girl sprained her left foot. The foot became swollen but the discomfort was not so great that a visit to the doctor was required. At the age of 5½ the Orthopaedic Department was consulted since the feet were of unequal growth the left foot smaller with a tendency of hallux valgus deformity. At the X-ray examination of that time (Figure 1) metatarsal bones 1-4 and the phalanges to no 2 and 3 toes were attacked by a concentric atrophy. The cancellous structure in the remaining bone was coarse. The girl was examined repeatedly during the course of 6 years. She had several spontaneous fractures (Figure 2) which healed with callus but the atrophy progressed constantly and even the callus formation underwent osteolysis. Figure 3 shows the condition after almost 8 years of observation. The disease also spread to a number of tarsal bones. The left foot is clearly smaller. The calf musculature is moderately atrophied (Figure 4). The 5th metatarsal bone and phalanges of the large toe are fairly well preserved. Discolouring of the skin was not observed. During acute phases with spontaneous fractures there was moderate pain and swelling. The patient manages well with protective arch support.

Figure 1 Appearance of unaffected right foot (above) and of left foot at first roentgen examination 1-3 metatarsals and phalanges in second and third toes show concentric atrophy. The structure of the bone is partly loose. Moderate hallux valgus. Child 5½ years.

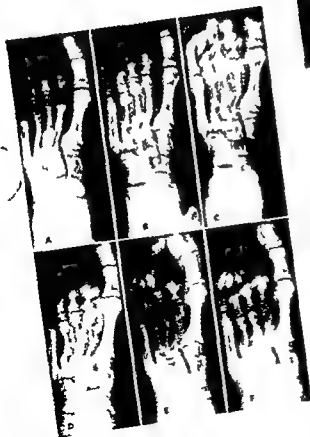
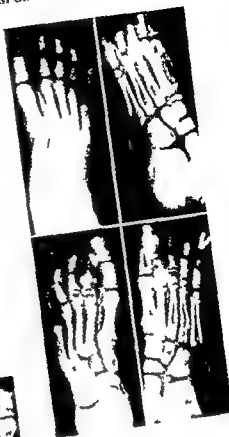


Figure 2 Frontal view of left foot during follow up: A) 2 years B) 3 years C) 3 years 1 month D) 3 years 8 months E) 4 years and F) 4½ years. Slow progress. Spontaneous fractures partly healing with callus formation also affected by progressive osteolysis.

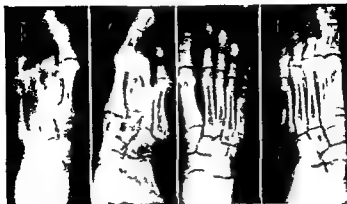


Figure 3 The affected left foot and the unaffected right foot after 11 years observation. Diaphysis of 4th metatarsal resected for biopsy. Disease also affected several tarsal bones. Phalanges of great toe as well as all 5 metatarsals are fairly well preserved.

as the sole therapy and she is able to go to school normally. Radiological therapy has been discussed but in view of the poor results previously reported we have not given such treatment.

The remaining skeletal parts were normal; the lung X-rays normal and also the kidney examination. The SR was normal as were the blood phosphorus, serum albumin, blood calcium and calcium in the urine. Only the alkaline phosphatases were slightly raised during acute phases of the disease.

After an observation period of four years an operation was carried out extirpating the diaphysis of the 4th metatarsal bone for the purpose of histological examination. At the operation the residual bone was roughened. The articular cartilage was intact. The tissue adjoining the bone was greyish yellow and no bleeding from this tissue could be ascertained at the operation.

HISTOLOGICAL EXAMINATION

Large sections of the bone tissue were replaced by a loose partly angiomatous like tissue with numerous thin walled vessels predominantly constructed like lymph vessels (Figures 5 and 6). In various directions an obvious inflammatory element was present in the form of lymphocyte infiltration and here and there pictures of non specific granulation tissue were observed in association with partially necrotic bone showing osteoclastic bone resorption (Figure 7). There were no pictures of lymphangiomatous proliferation into surrounding soft tissues.



Figure 4 Photograph of both feet after 3 years observation

DISCUSSION

In previous published cases the angiomatous tissue demonstrated at the histological examination very often resembled the hemangioma (2 7 8 9 11 16 17 20 23). Pictures resembling the lymphangioma were also described (4 6 22 23). Even a mixture of both types was found (10). Only a few authors saw osteoclasts in the histological picture (12 18). In our present case we discovered osteoclastic resorption.

The case previously reported by *Fallmer* and *Tilling* and the present case offer similarities in the histological picture with lymphangiomatosis. In both cases the operative findings with none or only slight bleed

Figure 5 Bony tissue largely substituted by loose vascular and partly angiomatous tissue with numerous thin walled vessels of preponderantly lymphatic structure

Figure 6 The same as in Figure 5 but in higher magnification

Figure 7 Area with slightly chronic unspecific inflammation adjacent bone destruction with osteoclasts



ing from the pathological tissue may also support this diagnosis. However, in other reported cases with hemangioma of the bone the surrounding soft tissue was also invaded which is obviously not so in the present case (14). In discussing the pathogenesis two views may be presented.

A The lesion may represent a primary angiomatous process that is of neoplastic type. Against this there are the characteristics mentioned above that the surrounding soft parts are evidently not involved and that the process is not expansive but atrophying. In this respect it may be mentioned that the case reported by Falkmer & Tilling (6) which was reported in 1956 and followed up in 1966 did not show expansion of the process.

B The lesion may represent an infectious or toxic bone injury with necrosis and resorption of bone tissue and also the development of granulation tissue of a non specific type with an abundance of vessels. The persistence of this granulation tissue would possibly give its angiomatous character to the histological picture.

The present case which throughout the observation period showed progress clinically is extremely interesting owing to the osteoclastic bone resorption demonstrated histologically and to the occurrence of an inflammatory process. The case would thus perhaps offer some support to alternative B above.

Typical of the radiological findings is the continuous progress of the disease over a long period very often invading adjacent bone but also leaving adjacent bone intact at other times.

SUMMARY

A case is reported of disappearing bone disease in a girl observed for fully 8 years. The osteolytic process affected a number of bones in the left foot. As in previously described cases an angioma like tissue was found at the site of the affected bone. In addition non specific granulation tissue and signs of osteoclastic bone resorption were present. The last mentioned findings are briefly discussed from a pathogenetic view point.

RESUME

Il est rapporté un cas de maladie comportant chez une fille une disparition d'os. Ce cas a été suivi pendant six ans. Le processus ostéolytique touche un certain nombre d'os du pied gauche. Comme dans les

crs décrits antérieurement un tissu similaire à un angiome a été trouvé à l'endroit de l'os atteint. De plus il y avait aussi un tissu de granulation non spécifique et des signes de résorption ostéoclastique de l'os. Il est discuté brièvement des dernières trouvailles mentionnées en partant d'un point de vue pathogénétique.

ZUSAMMENFASSUNG

Der Fall einer verschwindenden Knochenkrankung bei einem Mädchen das für volle 6 Jahre beobachtet wurde wird berichtet. Der osteolytische Prozess befiel eine Anzahl von Knochen im linken Fuss. Wie in früher beschriebenen Fällen wurde ein angiom ähnliches Gewebe am Sitze des erkrankten Knochens gefunden. Ausserdem waren noch unspezifisches Granulationsgewebe und Zeichen von osteoklastischer Knochenresorption vorhanden. Die zuletzt erwähnten Befunde werden von einem pathogenetischen Gesichtspunkt aus kurz besprochen.

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REFERENCES

1. Abell J M Jr & Badgley C E. (1961) Disappearing Bone Disease. *JAMA* 177 771-773.
2. Aston J N. (1958) A Case of Massive Osteolysis of the Femur. *J Bone Jt Surg* 40B 514-518.
3. Bickel W H & Broders A C. (1947) Primary Lymphangioma of the Ileum. Report of a Case. *J Bone Jt Surg* 29 517-529.
4. Blundell G, Jones R L & Stewart M. (1958) Massive osteolysis—Disappearing Bones. *J Bone Jt Surg* 49A 501.
5. Branco F & Horta J Da S. (1958) Notes on a Rare Case of Essential Osteolysis. *J Bone Jt Surg* 40B 519-527.
6. Falkmer S & Tilling G. (1956) Primary lymphangioma of Bone. *Acta orthop scand* 26 99-110.
7. Gorham L W & Stout A I. (1954) Hemangiomatosis and its relation to massive osteolysis. *Tr A Am Physicians* 67 307-307.
8. Gorham L W & Stout A I. (1955) Massive osteolysis (acute spontaneous absorption of bone phantom bone disappearing bone) its relation to hemangiomatosis. *J Bone Jt Surg* 37A 983-1004.
9. Gorham L W, Wright A W, Schultz H H & Maxon, F C, Jr. (1958) Disappearing bones: rare form of massive osteolysis: report of two cases, one with Autopsy. *Radiology* 71 43-47.

- 10 Halliday D H Dahlin D C Pugh D G & Yong H H (1964) Massive Osteolysis and Angiomatosis *Radiology* 82 637-644
- 11 Hambach R (1958) Zur Morphologie der massiven Osteolyse *Zentralblatt für allg Pathologi und Path Anatomie* 98 298-306 Jena
- 12 Iancu IL & Vargha A (1962) Ein Fall von progressiver kryptogenetischer Osteolyse des Unterkiefers *Radiologia diagnostica Int Zeitschrift für das Gebiet der Röntgendiagnostik* 3 571-573
- 13 Jackson J B S (1838) A singular case of Absorption of Bone (a Boneless Arm) *Flitorial Boston M and S J* 18 366-369
- 14 Jaffe H I (1939) Tumors and Tumorous Conditions of the Bones and Joints II 238 Lea and Febiger Philadelphia
- 15 Johnson I M & McClure J G (1958) Observations on massive osteolysis: review of literature and report of case *Radiology* 71 28-47
- 16 Jones H H Midgley R L & Smith C S (1958) Massive osteolysis: disappearing bones *J Bone Jt Surg* 40B 494-501
- 17 Ivashcheva C I (1960) On spontaneous bone absorption *Ortopediya trauma tologiya i prote irovanie Moskva and Charkov* 21 14-18
- 18 Milner S M & Baker S L (1958) Disappearing bones *J Bone Jt Surg* 40B 502-513
- 19 Shopfner C E & Allen R P (1961) Lymphangioma of bone *Radiology* 76 449-453
- 20 Stout A P (1959) Massive osteolysis *Radiology* 73 435-436
- 21 Thoma L H (1933) A case of Progressive Atrophy of the Facial Bones with complete Atrophy of the Mandible *J Bone Jt Surg* 15 494
- 22 Tucker A S (1964) Lymphangiectasis Benign and Malignant *The American Journal of Roentgenology Radium Therapy and Nuclear Medicine* III 1104-1113
- 23 Van de Veljer (1960) So called essential osteolysis *Nederlandsch tijdschrift voor Geneeskunde* 545-547

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FRACTURE OF THE LATERAL PROCESS OF THE TALUS

Supination Dorsal Flexion Fracture

By

O FJELDBORG

Received 2 VII 67

While I was working at the Orthopaedic Hospital Aarhus Professor Thomassen asked me in connection with an analysis of his club-foot material to investigate the mechanical features of the normal foot. Only one detail of this complex kinetic system will be described here.

During supination the calcaneus turns in relation to the talus on an axis proceeding dorso medially from the neck of the talus downwards and postero laterally to the lateral surface of the tuberosity of the calcaneus (Figures 1 and 2).

This axis has been described by Donit¹ (1903) Brockman (1930) Thomassen (1941) and others. In this movement the calcaneus performs plantar flexion adduction and various rotation as the angle between the talus and calcaneus is reduced.

If small windows are cut into the joint capsule it may be seen that during maximum supination there is no congruence between the joint surfaces in the talo-calcaneal joint—as shown in Figure 2 and sketched in a somewhat exaggerated way in Figure 3. This phenomenon has previously been described by Donit¹ (1903) who observed it using an entirely different technique.

Thus a fracture of the lateral process of the talus may arise from a fall on the dorsally flexed supinated foot (Figure 3).

It might be anticipated that such a fracture would occur in three stages: fissure (Figure 6) displaced fracture (Figure 7) and fracture with a supination dislocation in the talo-calcaneal joint the calcaneus being pushed forward in relation to the talus (Figure 8). Figures 4



Figure 1



Figure 2

Figure 1 Normal position of the talus and calcaneus. Congruence between the joint surfaces

Figure 2 Supination in which the joint space gapes a bit posteriorly there being contact only at the site of the lateral process of the talus



Figure 3



Figure 4



Figure 5

Figure 3 Fracture mechanism in the dorsally flexed supinated hindfoot. To facilitate understanding the incongruence in the talo-calcaneal joint is exaggerated. The weak spot of the system is the lateral process of the talus.

Figure 4 A similar fall injury on a dorsally flexed foot but with the talo-calcaneal joint in the normal position in which the joint surfaces are congruent. The weak spot is the neck of the talus.

Figure 5 A fall injury on a foot in the normal anatomical position. In this position the anterior edge of the tibia does not play any role. There is congruence between the joint surfaces in the talo-calcaneal joint. The weak area is the body of the calcaneus.

and 5 illustrate the relationship to two other types of fracture of the hindfoot.

All this was still theory without confirming examples. Later while I was in the Department of General Surgery of the Municipal Hospital Aarhus, I checked the X rays of all foot injuries for more than a year before discovering the first case (Figure 6).

A housewife aged 57 had fallen 1½ m and landed on a stone step



Figure 6



Figure 7



Figure 8

Figure 6 Fracture of the lateral process of the talus stage 1 (fissure)

Figure 7 Fracture of the lateral process of the talus stage II (fracture with displacement of the lateral process of the talus)

Figure 8 Fracture of the lateral process of the talus stage 3 (with subtalar dislocation)

On admission she had swelling of the ankle region but no tenderness of the malleoli. Passive movements in the subtalar joint gave rise to severe pain anterior to the lateral malleolus. X rays of the right ankle joint supplemented by tomography revealed a fracture line without displacement through the lateral process of the talus (Stage 1) (Figures 9 and 10).



Figure 9



Figure 10

Figure 9 Fracture of the lateral process of the talus stage 1

Figure 10 Anteroposterior tomography of the same fracture as shown in Figure 9

After two months of treatment in a plaster cast the fracture united. At follow up 18 months later the X ray appearances were normal and the patient had no complaints.



Figure 11 Fracture of the lateral process of the talus stage 2

A fortnight after the first case Case 2 arrived. A 60 year-old labourer had fallen 1 m after the ladder on which he had been standing broke. There was swelling of the ankle region and distinct tenderness anterior to the lateral malleolus. No tenderness of the malleoli. X rays revealed a displaced fracture of the lateral process of the talus (Stage 2) (Figure 11).

The completely detached fragment of the process was removed surgically followed by immobilization in plaster for 8 weeks.

At follow up 18 months later the patient was working but had slight osteoarthritic complaints. Movements in the ankle joint and subtalar joint were slightly restricted and X rays showed apart from the missing lateral process of the talus some narrowing of the joint space in the tibiocalcaneal joint. About 1 year after the first two patients Case 3 was admitted.

A 63 year-old psychotic man had jumped out of a first floor window. There was considerable swelling of the ankle region with severe tenderness of the malleoli and dorsum of the foot. The foot was in a position of slight varus. X rays revealed subtalar dislocation with separation of the lateral process of the talus (Stage 3) (Figures 8 and 12). After reduction of the dislocation the nature of the injury was easier to assess.

In the last two cases (Figures 11 and 12) the anterior process of the calcaneus acting as a buffer caused a compression fracture of the cuboid bone.

The patient was immobilized in a plaster cast for 8 weeks. Six months later he still had some pain when walking. X rays showed

Figure 1^a Fracture of the lateral process of the talus stage 3

Figure 13 Same foot as in Figure 12 after reduction of the dislocation



union of the fracture but severe osteoporosis of the entire region. Since then it has proved impossible to get in touch with this patient.

In each of these cases the fracture was produced by a fall the patient landing on the injured foot but none of the patients could describe the details of the event.

At about the time that we saw Case 3 this type of fracture was reported in a single case by Haage (1961) who did not enter into its mechanism and by Dimon (1961) who reported 3 cases 2 of which had been overlooked for 6 weeks. Dimon advanced various theories to explain the fracture mechanism all of which differ from that described above. He believed that the most likely cause was a forced pronation. Dimon referred to Bonin (1930) who described this fracture and also felt that it was due to a pronation trauma. Previous publications have not described stages in this type of fracture.

The conditions which occasion a fracture of this type are presumably rare. Like Dimon I believe that the fracture may be easily overlooked and that an overlooked fracture may just like other intra articular hind foot fractures result in serious consequences to the mechanical function of the foot.

SUMMARY

In the author's opinion a fracture of the lateral process of the talus is due to a supination-dorsal flexion trauma. Three cases representing three different stages of this fracture are reported.

RESUME

De lavis de l'auteur une fracture d'une tubérosité du talon est due à un trauma de flexion de supination dorsale. Trois cas représentant trois différentes phases de cette fracture sont rapportées.

ZUSAMMENFASSUNG

Der Verfasser ist der Meinung dass der Bruch des Processus lateralis tali auf ein Trauma mit Supination und Dorsalflexion zurückzuführen ist. Drei Fälle die drei verschiedene Stadien dieses Bruches darstellen werden berichtet.

REFERENCES

- Bonnin J G (1950) *Injuries of the Ankle* p 384 New York. Grune and Stratton
1950 London William Heinemann
- Dimon J H (1961) Isolated Displaced Fracture of the Posterior Facet of the Talus
J Bone Jt Surg 43 A 275
- Dönlitz A (1903) *Die Mechanik der Fusswurzel* Diss med Berlin
- Haage H (1961) Isolierte fraktur des Processus fibularis Tali *Fortschr ad Geb
d Röntgenstrahlen* 93 422
- Thomassen E (1941) Der angeborene Klumpfuß *Acta orthop scand* XII 40

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CHANGE OF FORM OF THE FOOT AND THE FOOT SKELETON UPON MOMENTARY WEIGHT BEARING

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Received 15 vi 67

An often discussed question is that which concerns the behaviour of the arch of the foot and of the foot skeleton during weight bearing of the foot. The answers to this question which can be found in the literature are by no means uniform. Benninghoff states for example in his book on anatomy 1949 that the navicular bone is depressed on weight bearing of the foot by 6.5 mm on average. Fick mentions in this respect the figure 8 mm and adds that the bones of the whole foot are depressed but that their mutual positions do not change when the foot bears weight. According to the investigations of H. Virchow¹ the foot arch prolonged 19 mm within the second ray and 8 mm within the fifth ray upon weight bearing. At the same time the foot becomes broader so that the distance between the bases of the first and fifth metatarsals increases by a mean figure of 15 mm. In a radiological study of the foot a change of form over a short and long period of weight bearing. Weismann considered that he was able to demonstrate that X rays taken of a weight bearing and a non weight bearing foot were identical or almost identical. If any difference existed it consisted in a minor elevation of the foot arch when the foot bore weight. At the same time the foot's length became somewhat less. This change in shape was explained by saying that when the foot bore weight the short plantar foot muscles were activated together with the posterior tibialis muscle the flexor hallucis longus and the peroneus longus. By means of this muscle action the arch of the foot was apparently main

¹ According to G. Hohmann: Fuss und Bein fünfte ergänzte Auflage Verlag J. F. Bergmann München 1931

turned and even elevated upon weight bearing. Electromyographic studies of later years showed however that upon static weight bearing of the foot *e.g.*, in an upright symmetrical rest position, none of the foot's muscles were in action. Static weight bearing of the foot must therefore signify an increased load on the ligamental apparatus of the foot. How the ligamental apparatus behaves upon receiving large momentary loads has not previously been investigated.

In order to obtain information concerning this and to form an independent view of the change in the normal foot on momentary weight bearing, —since the literature could not provide satisfactory details of this—a radiological and anthropometric study of a series of clinically normal feet was undertaken. Moreover the Swedish shoe industry had put the question to the authors of this article of whether and how the form of a healthy foot was changed upon momentary weight bearing *e.g.*, when trying on shoes. The problem was therefore of both anatomical and practical economic interest.

MATERIAL AND METHOD

Nineteen students of the Royal Gymnastic Central Institute in Stockholm were examined. 10 of these students were male and 9 were girls. Their age varied between 19 and 22 years and their body weights between 50.7 and 96.8 kgs. None of those taking part in the tests had any foot trouble nor had anyone experienced it previously. Clinically and orthopaedically the individuals exhibited certain variations in the shape of the foot but these were of such slight degree that the test group could be regarded as forming a normal series.

X-rays were taken of the left foot as the test individual stood upright on both feet. As underlying support for the left foot a 2 cms thick plate of plastic was employed which was fixed horizontally above a force plate (Figure 1b) (Carlsson 1967). Between the plastic plate and the force plate there was a narrow gap large enough to accommodate an X-ray plate. Two metal wires were inserted into the plastic plate at right angles to each other the one longitudinally and the other transversely so that their point of intersection lay approximately at the centre point of the plastic plate. The metal wires formed a coordinate system. Three X-ray tubes were firmly directed towards this coordinate system. Longitudinally along one side of the plastic plate and transversely along one short side there were placed two cassette holders for lateral (1d) respectively axial (1e) radiographs. In the former cases the rays passed in a latero-medial direction and in the latter case in an anterior-posterior direction. On the film lying beneath the plastic plate frontal pictures were taken. A lead indicator about 2 x 2 mm in size was fixed to the skin above the tuberosity of the navicular bone. The foot was positioned on the plastic plate in the angle formed by the two upright cassettes and with the heel and the medial aspect of the foot in contact with the cassettes (Figure 1). The longitudinal axis of the foot then lay approximately directly above the longitudinal wire in the

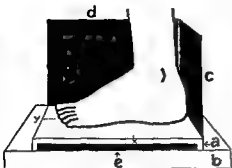


Figure 1 Diagram of foot and position of X-ray plates a) plastic plate supporting foot b) force plate c) d) e) X-ray plates

plastic plate and the tuberosity of the navicular bone was in the same frontal plane as the transverse wire. The focus film distance was 100 cms for all three projections. In the lateral projection the central ray passed horizontally and at right angles to the film 6 cms above the supporting surface of the foot and on a plane with the transverse wire in the plastic plate \pm through or very close to the lead indicator above the tuberosity of the navicular bone. The central rays of the other two X-ray tubes were ranged on a plane with the longitudinal wire in the plastic plate and thus with the longitudinal axis of the foot. Both tubes were placed in front of the test individual. The focus on the X-ray tube with which the axial picture was taken lay 7 cms higher than the intersection point between central ray and film. It was calculated that the ray would pass through the talo crural joint and thus form an angle of approx 4° with the horizontal plane through the joint. The axial pictures were not however utilised in drawing up the results given below. The central ray of the frontal picture passed a point on the longitudinal wire in the plastic 9 cms before the point of intersection between the two wires and making a forward open angle with the horizontal plane of 8° .

As a support for the right foot a wooden bench was placed about 30 cms from the force plate and level with the plastic plate on the force plate.

That part of the weight of the body which was borne by the left foot and thus by the force plate was recorded on a Honeywell visicorder. In quick succession three pictures were taken one by each of the X-ray machines when the test individuals stood in the following three positions a total therefore of nine pictures. The first three pictures were taken in a symmetrical standing rest position with the body weight evenly distributed over the right and left foot. With this foot position maintained almost the whole of the body weight was then transferred to the right foot by means of a careful inclination of the body to the right. This position is called below asymmetrical rest position A and the left foot is regarded as unloaded. Afterwards body weight is transferred in a similar way to the left foot and this position is called asymmetrical rest position B and the left foot is designated max loaded.

In order to obtain a preliminary understanding of the changes in position of the bones of the foot with the various loads the X-rays were examined in a stereocomparator. Two pictures were placed in this apparatus the one picture of an unloaded foot and the other of the same foot max loaded or symmetrically loaded. Even if the identification of various skeletal points is not completely exact this procedure

is nevertheless far superior to a two dimensional reading (Hallerf 1953). The points and contours which were utilised as measuring points are shown in Table 1.

Table 1. Measuring points on radiographs of the foot and the distal end of the leg

Lateral pictures

- 1 Furthest anterior point of tibia
- 2 Furthest posterior point of tibia
- 3 The most proximal point of the trochlea of the talus
- 4 Proximal anterior tip of the head of the talus
- 5 Furthest anterior point of the head of the talus
- 6 Distal tip of fibula
- 7 Furthest posterior point of calcaneus
- 8 Furthest plantar point of calcaneus
- 9 Furthest anterior point of calcaneus
- 10 Proximal dorsal point of navicular bone
- 11 The dorsal proximal tip in the joint cavity in the carpo metatarsal joints
- 12 The dorsal distal tip in the joint-cavity in the carpo metatarsal joints.
- 13 Furthest distal point of the cuboid
- 14 Furthest plantar point of the base of the 5th metatarsal bone
- 15 Furthest plantar point of the head of the 5th metatarsal bone
- 16 Furthest dorsal point of the head of the 1st metatarsal bone
- 17 Furthest anterior point of the head of the 1st metatarsal bone
- 18 Furthest plantar point of the head of the 1st metatarsal bone

Frontal pictures

- 1 Furthest medial point of the head of the 1st metatarsal bone
- 2 Furthest medial point of the head of the 2nd metatarsal bone
- 3 Furthest medial point of the head of the 3rd metatarsal bone
- 4 Furthest medial point of the head of the 4th metatarsal bone
- 5 Furthest medial point of the head of the 5th metatarsal bone
- 6 Furthest lateral point of the base of the 1st metatarsal bone
- 7 Furthest lateral point of the base of the 2nd metatarsal bone
- 8 Furthest lateral point of the base of the 3rd metatarsal bone
- 9 Furthest lateral point of the base of the 4th metatarsal bone
- 10 Furthest lateral point of the base of the 5th metatarsal bone
- 11 Furthest medial point of the cuneiform bone
- 12 Furthest medial point of the navicular bone
- 13 Furthest lateral point of the cuboid
- 14 Furthest distal point of the head of the talus
- 15 Furthest distal point of the calcaneus

The measurements in the stereocomparator showed that the changes in position of the measuring points in the lateral pictures were considerable. Differences of up to 5 mm often occurred. On the other hand the differences in the frontal pictures were small. These conditions show that as was expected the changes of position occur principally in a craniocaudal direction. A completely satisfactory measurement

Figure 2 Foot measuring instrument by Haraldson with force plates mounted type Wet enstein



of the size of these craniocaudal displacements as well as sagittal displacements cannot be carried out however. Certain rotatory movements may arise in weight bearing of the foot which make difficult and indeed impossible an identification of the measuring points which is free from objection. Nevertheless a precisely executed measurement of the lateral pictures can produce values which are sufficiently reliable to be used as a basis for an evaluation of the change in form of the foot skeleton in those individuals examined who were given the varying loads.

In measurements of radiographs taken on two different occasions, in one case on three different occasions and in one case on five different occasions—the values were almost identical. No variations in the readings occurred of such magnitude that they could affect the conclusions to be drawn from the investigation if the distal tip of the fibula is excepted, i.e. point 6 on the lateral pictures. These variations are due to changes in the position of the ankle joint.

In the measurements of the lateral pictures an orthogonal coordinatograph was used of the type Simonson and Hultmalm. The coordinate system was placed over the radiograph so that its y axis passed through the dorsal top of the lead indicator above the tuberosity of the navicular bone and its x axis coincided with the weight bearing plan of the foot (more precisely the longitudinal wire inserted into the plastic plate).

The external shape of the foot and the contour changes were measured by Haraldson's foot measuring instrument (SFI publication 1954) under the same weight bearing conditions as in the radiological studies, i.e. with a symmetrical and maximally loaded foot and also with an unloaded foot. Two force plates were used to record the foot loading, one for the heel and one for the fore foot (Figure 2) (Wet enstein 1964, Carlsson 1964). In this way it could be checked that the percentage distribution of weight on the heel and fore foot remained unchanged when the total loading was changed. Of the measurements taken with Haraldson's measuring instrument, foot length, ball breadth and the circumference of the ball were utilised. By ball breadth is meant the external distance between the medial border of the head of the 1st metatarsal bone and the lateral border of the head of the 5th metatarsal bone. The circumference of the ball was measured level with these two measuring points. The accuracy of the method was tested by two investigators with four double measurements. The difference was never more than 1 mm.

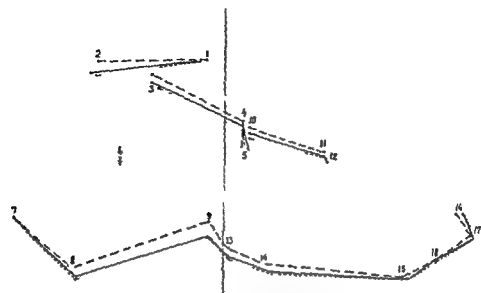


Figure 3 Position of measuring points with varying loads of the foot

- non loaded foot
 - - - - - symmetrically loaded foot
 maximally loaded foot

RESULTS AND DISCUSSION

Figure 3 shows the internal position of the measuring points and their position in relationship to the coordinate system of the orthogonal coordinate-graph in one case with the three varying loads. The corresponding tracings of the other 18 cases will be found in Figure 4. In order to clarify the displacement of the measuring points and so the change in form of the skeleton the measuring points were connected by straight lines. Link lines 1-2 show changes in position of the distal end of the tibia. Link lines 3-4-5 refer to the tibia. Link line 10-11-12 represents the dorsum of the foot at its medial border. The link line 7-8-9 concerns the calcaneus and 13-14-15 the cuboid and metatarsal V and 16-17-18 indicates the head of metatarsal I.

The straight line which connects measuring point 7 with measuring point 17 is called here foot length and the distance at right angles from point 3 to the straight line which passes through points 9 and 15 is called foot height. As Figures 3 and 4 show, in one case the foot length increased by 3 mm (case 6) while no change in length could be measured in the other cases. The changes in foot height were also

so insignificant—a mean of 0.15 mm.—that one cannot speak of any true changes in the form of the foot skeleton during weight bearing of the foot.

The anthropometric measurements showed no significant difference in either foot length or ball breadth in differing loadings of the foot. The average difference did not extend to 1 mm. On the other hand there was a systematic difference in the circumference of the ball upon various loads with an average difference of + 4.0 mm. between unloaded and maximally loaded foot and + 2.5 mm. between unloaded and symmetrically loaded foot. Foot length and ball breadth are principally skeletal measurements while the circumference of the ball is a soft tissue measurement. These anthropometric measurements coincide fully with the radiological i.e. the foot skeleton does not undergo any demonstrable changes in position in the sagittal and transverse direction when the foot bears weight. The increase in width within the region of the ball of the foot i.e. within the region of the metatarsal heads which arises on weight bearing of the foot seems therefore to be a soft tissue change. When the foot bears weight the subcutaneous tissue is pressed together and displacements in a medial and lateral direction occur and produce stretching of the tissues so that measurable increases in volume arise.

Since the muscles of the foot do not seem to be in action on static weight bearing in a symmetrical standing rest position (*Basmajian & Benzon* 1954 and others) then this must mean that the ligamental mechanism and plantar aponeurosis play a decisive role in the stability of the foot skeleton even if the passive resistance of the muscles to stretching and the internal positional relationships of the skeletal parts may contribute to stability. The fact that the foot skeleton is considerably more depressed in passing from unloaded to symmetrically loaded foot than from symmetrically loaded to maximally loaded foot is in full accordance with the rheological qualities of the connective tissue even though the increase in load is the same on the whole in both cases. Thus studies of stress strain behaviour in specimens of ligament tendon and other connective tissue structures show that the degree of stretching is not proportional to the load but decreases considerably with increased load. Therefore the passive forces in the material studied can fix the different joints of the foot so powerfully that when the foot bears weight no true depression of the foot's longitudinal arch takes place.

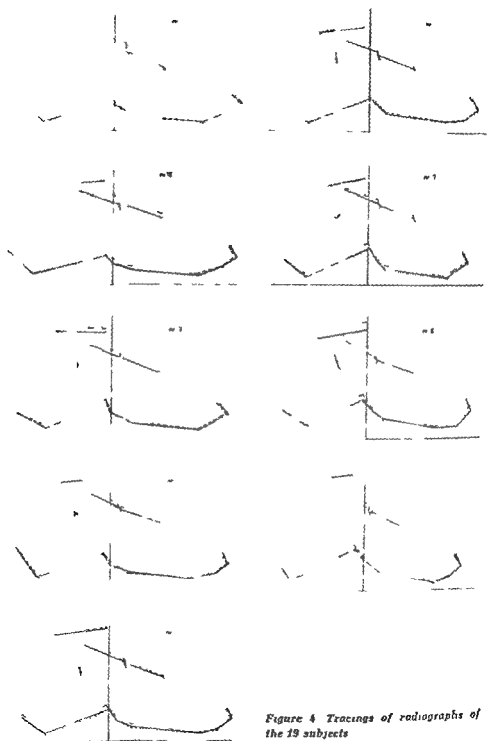
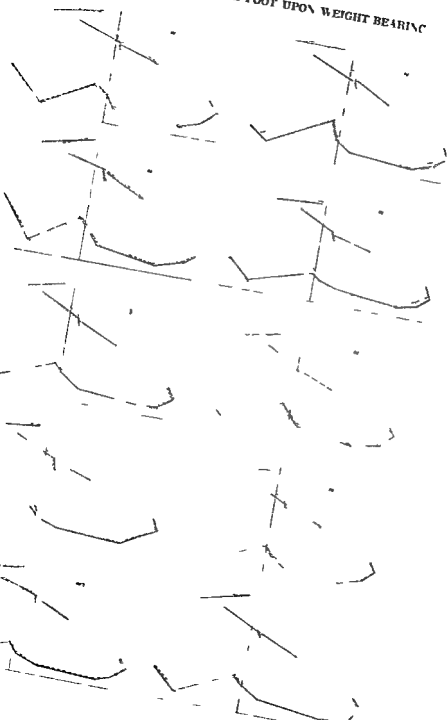


Figure 4 Tracings of radiographs of the 19 subjects



SUMMARY

A radiological and anthropometric investigation into changes of form of the foot and the foot skeleton on weight bearing was carried out on 19 students. Clinically and orthopedically the series is considered to be normal series. No changes in the form of the foot skeleton could be demonstrated. The external changes in form of the foot which arise when the foot bears weight are due to alterations and displacements of soft tissues. The active and passive supporting mechanism of the foot is discussed.

RESUME

Un examen radiologique et anthropométrique du pied et des modifications du squelette du pied dans des épreuves de charge a été effectué chez 19 étudiants. Au point de vue orthopédique clinique les sujets doivent être considérés comme un matériel normal. Il n'a pas été possible de constater une déformation du squelette du pied. Le changement extérieur de la forme du pied qui apparaît sous la charge est dû à une déformation et à un déplacement des tissus mous. Il est discuté de l'appareil de choc actif et passif du pied.

ZUSAMMENFASSUNG

Eine röntgenologische und anthropometrische Untersuchung der Formveränderung des Fusses und Fussknochens bei Belastung des Fusses wurde an 19 Studenten vorgenommen. Klinisch orthopädisch ist das Material als ein Normalmaterial anzusehen. Irgendwelche Veränderungen des Fussknochens konnte man nicht nachweisen. Die beobachteten äusseren Formveränderungen des Fusses bei der Belastung beruhen auf Deformierung und Verschiebung der Weichteile. Die aktiven und passiven Stützapparate des Fusses werden besprochen.

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REFERENCES

- Basmajian J V & Denton J W (1944) An electromyographic study of certain muscles of the leg and foot in the standing position. *Surg Gynec & Obst* **111** 669-666.

- Benninghoff A (1949) *Lehrbuch der Anatomie des Menschen* Vierte Auflage. Urban und Schwarzenberg Berlin-München
- Carlson S (1962) A method for studying walking on different surfaces *Ergonomics* Vol 5 No 2
- Carlson S (1964) Influence of frontal and dorsal loads on muscle activity and on the weight distribution in the feet. *Acta orthop scand* 33 299-309
- Hallert B (1953) *Podogrammetri* P A Norstedt och Söners Förlag Stockholm
- Hohmann G (1961) *Fuss und Bein* Fünfte ergänzte Auflage Verlag von J F Bergmann
- SFI publikation (Åke Norlander) (1954) *Foten* Istett och skott Emil Kihlström AB Stockholm
- Weitnauer H (1954-55) Formveränderungen des Fusses bei Ermüdung (Zugleich ein Beitrag zur operativen Behandlung des Knickfusses) *Zschrft Orthopadie* 83 119-127
- Wetzelstein H (1964) Eine Untersuchung der Fersenbelastung beim Gehen Eine Methode für die Messung der Fersenbelastung im Schuh *Acta orthop scand* Suppl 43

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CALCANEO NAVICULAR COALITION

Late Results of Resection

By

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INTRODUCTION

Up to 1920 calcaneo navicular coalition was considered an unimportant anatomical variant *Stomann* (1921) was the first to demonstrate a possible relationship between coalition and painful fixed hindfoot. He suggested treating the condition by resection, but feared further development of the pronation deformity found in all his cases.

Badgley (1927) and *Bentzen* (1928, 1932) reported the first results of resection.

Since that time numerous authors including *Hayd* (1949) *Webster & Roberts* (1951) *Rössler* (1956) *Hohmann* (1961) and *Mitchell & Gibson* (1967) have expressed the view that resection alone or combined with interposition of muscular tissue or other material was applicable for children provided that the shape of the foot was well preserved and that X-rays did not reveal any signs of osteoarthritis. The operation is followed by a period of immobilization. After treatment by supports in ordinary shoes.

In adults and adolescents who show radiological signs of abnormal pressure especially in the talonavicular joint there is, all authors agree, indication for arthrodesis either talo navicular (*Bentzen* 1928) or of further joints usually in the form of triple arthrodesis (*Badgley* 1927 *Rendu* 1928 *Seddon* 1933 *Harris & Beath* 1948 *Ernsting* 1956 *Sour* 1959 and *Heikel* 1962). Supplementary tendon transplantation is used by *Niederecker* (1955) among others.

The adherents of arthrodesis were not impressed by the results of resection but only *Mitchell & Gibson* (1967) have submitted a resected material followed for many years. From their analysis it is apparent

that by simple resection of the bar a satisfactory result was obtained in 76 per cent of 48 treated patients. The follow up period ranged from 4 to 13 years. The most favourable results were obtained in children younger than 14 years if they did not have deformity of the foot or signs of adaptive joint changes at the time of operation. As regards the mobility in the subtalar joint and the incidence of recurrence of the coalition their results are in keeping with those which will be reported below.

MATERIAL AND METHODS

The object of the present study was to assess the value of the method by a follow up study on resected cases of calcaneo navicular coalition.

Operative Method

Bentzen's technique (1928, 1932) dorsolateral incision over the coalition, detachment of the extensor digitorum brevis muscle from its origin. Resection of the coalition close to the navicular bone and calcaneus, interposition of the detached muscle belly into the defect left by the resection. The muscle is kept *in situ* by a pull-out wire through the sole. Plaster cast usually for 3 weeks. After treatment by supports in the shoes.

During the period 1936 to 1948 31 resections on a total of 25 patients (13 males and 12 females) were carried out in the Orthopaedic Hospital Aarhus. The right foot was treated in 13 cases, the left in 18. Six patients had the operation on both feet.

Six patients (2 males and 4 females) continued to have such painful feet that triple arthrodesis was performed secondarily in all cases on one side only, even in the 3 patients who had bilateral primary operations. Four of these patients had the arthrodesis within 2 years of the resection.

The resection series comprises 29 patients (13 males and 9 females) having a total of 25 operations, not followed by secondary arthrodesis.

The follow up study was carried out in the years 1953 to 1960. One patient who is a miner abroad was not examined but reported that he had no complaints from the foot, also not during heavy work. All the others were examined by the author. The follow up period ranged from 10 to 29 years. In 20 cases the follow up examination was done more than 15 years after the resection. Table 1 gives a survey of the material by side resected and by sex.

At the time of operation the patients were 11-23 years of age. Twenty had the operation before the age of 15 and only one was over 20. Half the feet had been painful for more than one year prior to the operation. The factors which elicited this pain were unknown in 25 cases. A possible occupational cause was stated by 5 while only one considered a mild injury to be responsible for the symptoms.

All presented themselves because of pain and/or fatigue in the foot and leg. No one adduced spontaneous complaints concerning the shape of the foot, and only one patient had noticed restriction of subtalar mobility. In 8 cases the complaints were so severe that the working ability was appreciably reduced.

According to the case records physical examination showed the foot to be in

neutral position or in slight pronation in 22 cases severe pronation in 8 and with slight cavus deformity in one Subtalar mobility was stated to be normal in one case distinctly reduced in 8 and abolished in 2?

Table 1. Cases of calcaneo navicular coalition treated by resection

	Males		Females		Total
	Right	Left	Right	Left	
Resection after examined	4	8	0	6	14
Primary resection secondary triple arthrodesis after examined	2	0	1	3	6
Resection not after examined	0	1	0	0	1
	6	9	7	9	31

Iostoperatively one patient went into mild shock and one developed negligible infection in the wound while all other operations were uncomplicated

After the plaster cast removed about 3 weeks after the operation all the patients used supports in the shoes at least for a few months

The period off work after the operation was in most cases only weeks to a few months However 2 patients were off work for more than 6 months because of persisting pain in the foot Three males and one female had to change their occupation because of the foot. This change of occupation became permanent only in the case of 2 of the males

Prior to the operation all the patients were X-rayed with special regard to calcaneo navicular coalition (Stomann 1926) In 15 cases exposures were made also in the dorsoplantar and lateral views Signs of osteoarthritis in the form of marginal exostoses narrowing of the joint space or subchondral sclerosis were demonstrated in 4 cases in the talo navicular joint and in one case also in the subtalar joints Six feet exhibited more or less marked halisteresis of the areas adjacent to the coalition while only one case had diffuse halisteresis of the entire foot

The bar presented itself in 4 cases as a solid bridge between the navicular bone and calcaneus All others were divided by a distinct gap in half the cases in the middle of the bar Among the other half an equal number had the gap closer to the calcaneus and closer to the navicular bone In one foot there was a tiny secondary os calcis in the gap

FOLLOW UP

Data concerning the history and social factors were recorded at the time of the physical examination of the lower limbs X-rays were obtained of the ankle joint and foot including a special coalition projection and the talo crural articulation was tested for instability

The resection material comprises 24 feet

Nine patients (9 operated feet) reported pain in the tarsus In 7 the

pain was slight and negligible and only 2 patients had more severe pain. Eight complained of a tendency to fatigue in the operated leg. One patient found the subtalar mobility to be inconveniently restricted. When asked about the appearance of the foot, 4 patients complained that it was too flat and three—all women—had problems in getting ready-made shoes that would fit them.

Five patients had done their military service after the operation but 2 of them had done only light service.

All the patients were working 21 under conditions where they stood or walked a lot & often on rough ground. All considered their earning capacity to be normal but 2 men felt that the foot was somewhat annoying in their work.

A total of 13 patients stated that they had no complaints at all on account of the foot no matter what they did. 9 felt discomfort from the foot upon special unaccustomed efforts while 2 patients were annoyed by pain in the foot.

At follow up the patients ranged in age from 24 to 39 years.

In 19 unilaterally operated cases there was atrophy of the lower leg amounting to 1 and 2 cm in 4 cases and to more than 2 cm in 2. The shape of the foot was normal or there was slight pronation in 19 cases, considerable pronation in 5.

Movement in the ankle joint, judged by the axis through the lower leg and a plane through the sole, varied from 35 to 65, average 42. This must be considered normal as tested by this technique. Subtalar mobility determined as an estimated percentage of the normal excursions was found to be abolished in 4, reduced in 9 and normal in 11 cases. This was a distinct improvement compared with the preoperative condition.

None of the patients walked with a limp when wearing shoes. Only one foot proved tender at the site of the subtalar joints.

All 24 feet and ankle joints were X-rayed at follow up. The ankle joints showed osteoarthritis in the form of slight marginal exostoses on the anterior edge of the tibia in 2 cases. The ankle joints were examined for instability by manual supination and pronation pressure upon the hindfoot in relation to the lower leg. The angle between the joint surfaces of the tibia and talus was measured. Total instability is stated as the sum of the supination and pronation tilting of the talus in relation to the tibia. In 17 ankle joints there was instability of 1° or less, in 3 ankle joints of 2°, in 2 ankle joints of 3°, while 1 ankle joint tilted 4° and 1 tilted 5°. This distribution cannot be considered abnor-

neutral position or in slight pronation in 22 cases severe pronation in 8 and with slight *cavus* deformity in one Subtalar mobility was stated to be normal in one case distinctly reduced in 8 and abolished in 22

Table 1 Cases of calcaneo navicular coalition treated by resection

	Males		Females		Total
	Right	Left	Right	Left	
Resection after examined	4	8	6	6	24
Primary resection secondary triple arthrodesis after examined	2	0	1	3	6
Resection not after examined	0	1	0	0	1
	6	9	7	9	31

Postoperatively one patient went into mild shock and one developed negligible infection in the wound while all other operations were uncomplicated

After the plaster cast removed about 3 weeks after the operation all the patients used supports in the shoes at least for a few months

The period off work after the operation was in most cases only weeks to a few months However 2 patients were off work for more than 6 months because of persisting pain in the foot Three males and one female had to change their occupation because of the foot This change of occupation became permanent only in the case of 2 of the males

Prior to the operation all the patients were X-rayed with special regard to calcaneo navicular coalition (Siomann 1926) In 15 cases exposures were made also in the dorsoplantar and lateral views Signs of osteoarthritis in the form of marginal exostoses narrowing of the joint space or subchondral sclerosis were demonstrated in 4 cases in the talo navicular joint and in one case also in the subtalar joints Six feet exhibited more or less marked halisteresis of the areas adjacent to the coalition while only one case had diffuse halisteresis of the entire foot

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RESULTS

Data concerning the history and social factors were recorded at the time of the physical examination of the lower limbs X-rays were obtained of the ankle joint and foot including a special coalition projection and the talo crural articulation was tested for instability

The resection material comprises 24 feet

Nine patients (9 operated feet) reported pain in the tarsus In 7 the

tion de la mobilité sub-talaire. Néanmoins les radiographies ont montré le retour d'une coalition dans les deux tiers des pieds et dans 23 sur 24 une ostéoarthrite déterminée dans l'articulation du tarse dite Chopart même avant que les malades aient atteint l'âge de 40 ans.

Dans ces conditions j'ai l'impression que la résection ne peut pas être recommandée puisque dans la plupart des cas elle est suivie d'ostéoarthrite. Une triple arthrodeuse doit être considérée comme étant plus sûre.

ZUSAMMENFASSUNG

Nach einer Zeitspanne von 10–22 Jahren wurden 31 Füße die ursprünglich mittels Resektion einer Coalitio calcaneonavicularis behandelt worden waren nachuntersucht.

In 8 Fällen war eine Tripelarthrodeuse sekundär ausgeführt worden. Die Ergebnisse der Resektion waren subjektiv in 13 Fällen gut während 9 Patienten noch leichtere Beschwerden und 2 starke Schmerzen hatten. Ein Patient wurde nicht gesehen berichtete aber dass er keinerlei Beschwerden hatte.

Die objektive Untersuchung zeigte eine gut erhaltene Form des Fusses gute Beweglichkeit im Knochelgelenk und oft Wiederherstellung der subtalaren Beweglichkeit. Röntgenbilder zeigten jedoch ein Wiederauftreten der Coalitio bei zwei Dritteln der Füße und 23 von 24 Füssen wiesen eine ausgesprochene Osteoarthritis besonders des Chopart Gelenkes auf selbst ehe die Patienten das Alter von 40 Jahren erreicht hatten.

Deshalb meine ich dass die Resektion nicht anzubefehlen ist da sie in den meisten Fällen von einer Osteoarthritis gefolgt wird. Tripelarthrodeuse muss als das sichere Vorgehen angesehen werden.

REFERENCES

- Badgley Carl E. (1927) Coalition of the Calcaneus and the Navicular. *Arch Surg* 14 75–85.
- Bentzon I. C. H. (1933) Coalitio calcaneonavicularis mit besonderer Bezugnahme auf die operative Behandlung des durch diese Anomalie bedingten Plattfusses. *Verh. dtsch. orthop. Ges.* 23 Kongress 1969.
- Bentzon I. C. H. (1935) Spätere Resultate der operativen Behandlung der durch Coalitio calcaneonavicularis bedingten Plattfusses. *Verh. dtsch. orthop. Ges. Beilageheft Z. orthop. Chir.* 53 374–375.
- Frusting (Ertroff) (1936) Zur klinischen Bedeutung der Coalitio calcaneonavicularis. *Arch. orthop. Unfall Chir.* 48 433–457.

- Harris R I & Beath Thomas (1948) Etiology of peroneal spastic Flatfoot. Special reference to talocalcaneal bridge *J Bone Jt Surg* 30 B 674-684
- Hayd F W (1949) Die Coalitio calcaneo navicularis und ihre klinische Bedeutung *Z orthop Chir* 78 292-303
- Heikel Henrik V A (1967) Coalitio calcaneonavicularis and calcaneus secundarius *Acta orthop scand* 32 1-84
- Hohmann G (1961) Coalitio calcaneo navicularis Handbuch der Orthopädie Georg Thieme Stuttgart
- Mitchell E P & Gibson J M C. (1967) Excision of calcaneo navicular bar for painful spasmodic flatfoot. *J Bone Jt Surg* 49 B 281-287
- Niederecher Kaspar (1955) Erfahrungen bei operativer Behandlung des Plattfusses. *Arch orthop Unfall Chir* 47 542-544
- Rendu André (1928) Traitement de la tarsalgie avec pied plat occasionnée par la synostose calcaneo scaphoïdienne *Rev Orthop* 15 612-673
- Rosler H (1956) Erfahrungen und Gedanken über die Fusskontrakturen bei Jugendlichen *Z Orthop* 87 555-570
- Seddon H J (1933) Calcaneo scaphoid coalition *Proc roy Soc Med* 26 419-424
- Slomann H C. (1911) On coalitio calcaneo-navicularis *J orthop Surg* 19 586-609
- Slomann H C. (1916) On the Demonstration and Analysis of calcaneo navicular coalition by Roentgen Examination *Acta radiol* 5 304-319
- Sour Robert (1959) Le pied plat contracturé *Rev Chir orthop* 45 817-830
- Webster F S & Roberts W M (1951) Tarsal Anomalies and Peroneal spastic Flat foot. *J Amer med Ass* 146 1099-1104

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RELATIONS BETWEEN FEMUR DENSITY AND STRONTIUM 85 UPTAKE IN BIPEDAL RATS

By

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The rate of entry of isotopes of calcium and strontium into bone is referred to as the accretion rate and is generally held to be a good parameter of bone formation rate in animals and humans (*Bauer 1954 Wendeberg 1961 Dymling 1964*). We have found (*Nilsson & Saville 1967*) that when rats sustain a fracture of the tibia the ipsilateral femur does not grow as fast as the contralateral femur. The twenty four hour uptake of strontium measured as per cent of dose per unit ash in the smaller femur on the fractured side is greater than that in the larger femur on the uninjured side but the same as that in a femur of the same volume and density from a smaller rat. This suggests that bone density rather than bone formation governs the uptake of radiostrontium under these conditions. To test this point further we have altered the relations between body weight and bone density by raising bipedal rats which have larger denser and stronger femora than normal rats of the same weight (*Saville & Smith 1966 Smith & Saville 1966*).

MATERIAL AND METHODS

In thirty four male Sprague Dawley rats of the Charles River strain bipedalism was accomplished shortly after birth according to the method of *Saville & Smith (1965)*. The animals were raised after weaning on a commercial rat diet. They were killed at pre determined weights between 50 and 300 g. Fifty six control rats of the same sex and strain fed the same diet were killed at approximately the same weight range. Twenty four hours before sacrifice each animal was injected subcutaneously with about three microcuries of strontium 85. The left femur was removed from each animal cleaned of soft tissue and weighed suspended from a fine copper wire in air and in water at 4 C. The volume was determined according to Archimede's Principle. The bones were ashed for forty eight hours at 600 C, the ash was

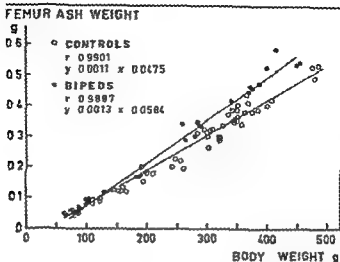


Figure 1 Femur ash weight is plotted as a function of body weight. Regressions are calculated by the method of least squares. There is a significant slope difference ($P < 0.001$).

weighed and transferred to test tubes where the radioactivity was measured in a well scintillation counter to a precision of 1 per cent. By comparing the counting rate of the samples to that of a known standard the activity was calculated and expressed as per cent of the injected dose. Regressions were calculated by the method of least squares and were compared one with another by analysis of covariance.

RESULTS

The ash weight of the femur was a linear function of body weight both in the controls and in the bipeds but at any given body weight the bipeds had significantly more ash ($P < 0.001$) (Figure 1). The volume of the femora also was a linear function of body weight in both groups but the bipeds had significantly greater volume at any given body weight ($P < 0.001$) (Figure 2). The density of the femora, expressed as grams of ash per cubic centimeter of bone, was a linear function of body weight in both groups but the bipeds had significantly greater bone density than the controls ($P < 0.001$) (Figure 3). The ash weight of the femora approximated a linear function of the femur volume in both bipeds and controls and at any given femur volume the ash weight was not significantly different in the two groups of animals (Figure 4). The specific activity of Strontium 85 was a negative exponential function of bone density and at any given bone density the specific activity

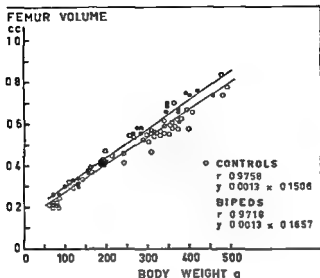


Figure 2 Femur volume is plotted as a function of body weight. Regressions are calculated by the method of least squares. There is a significant difference in adjusted means ($P < 0.001$).

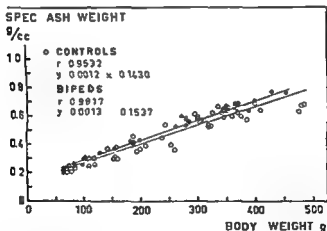


Figure 3 Ash per cc of femur is plotted as a function of body weight. Regressions are calculated by the method of least squares. Analysis of covariance shows a significant difference in adjusted means ($P < 0.001$).

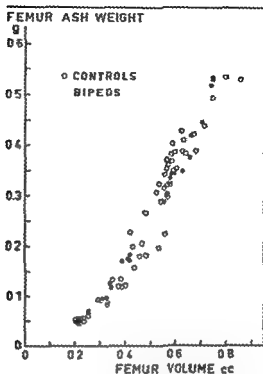


Figure 4 The ash content of the femora is plotted as a function of femur volume. At any given femur volume there is no significant difference in ash content in the two groups

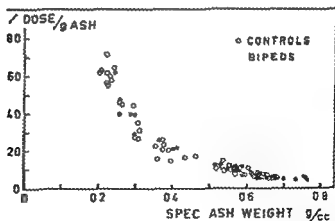


Figure 5 Specific activity of the femur is plotted as a function of femur specific ash weight. At any given specific ash weight there is no difference in specific activity in the two groups

was identical in both groups (Figure 5). In short bipedal femora are larger than controls of the same weight but they have just the right amount of Strontium 86 for bones of their density.

DISCUSSION

Bipedal rats have larger denser and stronger femora for their body weight than do controls. We have succeeded in disturbing the relation between body weight and femur growth in these animals. The changes thus introduced however did not interfere with the relationship of size, density and uptake of Strontium 86 . This supports our previous observation that bone density or a physical property of bone related to density is an important factor influencing the uptake of mineral tracer in the rat femur.

SUMMARY

The volume, the mineral content and the twenty-four hour uptake of Strontium- 86 were measured in the femora of bipedal and quadrupedal rats. The relationships of ash content to volume and of uptake of Strontium- 86 to density were not influenced by the changes of femur growth introduced by bipedalism.

RESUME

Le volume, la teneur en minéral et l'absorption pendant 24 heures de Strontium 86 ont été mesurés en les deux femurs sur des rats bipèdes et quadrupèdes. Le rapport entre la teneur en cendres et le volume et entre l'absorption de Strontium 86 et la densité ne sont pas influencés par les modifications de la croissance du fémur introduites par le bipédalisme.

ZUSAMMENFASSUNG

Das Volumen, der Mineralgehalt und die vierundzwanzigstündige Aufnahme von Strontium 86 wurden in den Femora von zwei- und viersfüssigen Ratten gemessen. Das Verhältnis von Aschengehalt zu Volumen und von Strontium 86 Aufnahme zu Dichtigkeit wurde durch die Veränderungen des Femurwachstums, die durch zweifüssigkeit hervorgerufen worden war, nicht beeinflusst.

REFERENCES

- Bauer G C H (1954) Rate of bone salt formation in a healing fracture determined in rats by means of radiocalcium *Acta orthop scand* 23 169
- Davling J F (1964) Calcium kinetics in osteopenia and parathyroid disease *Acta med scand Suppl* 175
- Nilsson B E R & Saville P D (1968) Influence of growth and trauma on bone mass and mineral turnover in rats *Acta orthop scand* 39 273
- Saville P D & Smith H E (1966) Bone density breaking force and leg muscle mass as functions of body weight in bipedal rats *Amer J Physiol Anthropol* 23 35
- Smith H E & Saville P D (1966) Bone breaking stress as a function of weight-bearing in bipedal rats *Amer J Physiol Anthropol* 25 159
- Wendeberg H (1961) Mineral metabolism of fractures of the tibia in man studies with external counting of Sr^{85} *Acta orthop scand Suppl* 57

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DIAGNOSTIC DIFFICULTIES IN LOWER CERVICAL SPINE DISLOCATIONS

By

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INTRODUCTION

The object of this paper is to point out the risk of overlooking fractures and dislocations in the lower part of the cervical spine and to describe a reliable diagnostic technique

Ebbehøj, in 1942 said that there are mainly three reasons why fractures of the spine are overlooked (1) The trauma has not been considered sufficient to cause a fracture of the spine (2) The primary symptoms have not been so violent as to suggest to the doctor a possibility of fracture (3) The X rays taken have been insufficient not visualizing the injury This third reason may be avoided when bearing in mind that A positive X ray finding means much at times everything in the diagnosis a negative finding means something but a negative finding in a poor X ray exposure means nothing at all

Others (*Braakman & Vinken* 1967 *Norton* 1962) have pointed out that in an X ray examination of the cervical spine it must be secured that all the vertebrae are visualized since not uncommonly a dislocation of C6 on C7 or of C7 on T1 will be overlooked because this region is superimposed by the shoulders in the lateral view

It must be admitted that by the current standard exposures of the cervical spine in patients with acute injuries it is not always possible to reveal dislocations between the lower cervical vertebrae These diagnostic difficulties are illustrated by the following two case histories

CASE REPORTS

(B 14761) A man aged 50 was admitted to a surgical department after having fallen 5 metres from a roof hitting the back of his neck against the ground He was complaining of severe pain at the back of the neck X rays of the cervical spine

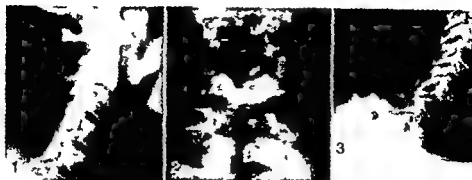


Figure 1 Lateral view taken in the recumbent position at the primary examination of Case 1

Figure 2 Anteroposterior view taken in the recumbent position at the primary examination of Case 1

Figure 3 Lateral view taken of Case 1 in the erect position 11 weeks later

revealed a fracture of the spinous process of C 2. Objective examination of the limbs did not show any neurological abnormalities. After 11 days in hospital he had out patient massage treatment of the back of the neck but as this aggravated the pain he stopped attending. Owing to persistent pain and to the appearance of paraesthesiae and a feeling of weakness in the right hand he was referred to the Orthopaedic Hospital—6 weeks after the accident. Here the findings were a severe restriction of movement in the cervical spine and hypalgesia radially on the right hand but no other neurological abnormalities. New X rays of the cervical spine in 4 projections and special views of the uppermost vertebrae again showed normal appearances apart from a blurred fracture of the spinous process of C 2. The lateral view as in the primary exposures showed the appearances only down to C 6 because of the superimposed shoulder (Figure 1). In the anteroposterior and oblique views the structures of the lowermost cervical vertebrae were somewhat blurred but this was interpreted as spondylotic changes. To immobilize the neck a plastic collar was fitted. At follow up 11 weeks after the accident the pain has disappeared. Objective examination still showed mild hypalgesia dorsally at the root of the right index finger and now a striking prominence of the spinous process of C 7 was noted. Therefore further X rays were obtained. In the lateral view it was now possible to visualize also C 7 and this disclosed total dislocation between C 6 and C 7 with displacement which measured four fifths of the width of the vertebral body and an angulation of 40° (Figure 3). The patient was now admitted and treated with Crutchfield skull traction for 3 months. Thereby the angulation was abolished and gradually the two vertebrae fused anteriorly. After treatment by plaster collar and later by plastic collar 9 months after the accident the site was stable there was restricted mobility in the neck but no neurological abnormality and the patient went back to work as a butcher.

(B 148 871) A man aged 36 was admitted to a surgical department with symptoms and signs of mild concussion after a motor accident. On the third day he complained

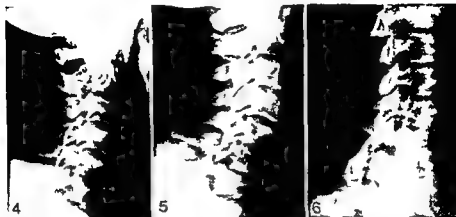


Figure 4 Lateral view taken in the recumbent position at the primary examination of Case 2

Figure 5 Lateral view taken 4 months later of Case 2 in the erect position

Figure 6 Oblique view taken 4 months later of Case 2 in the erect position

of pain at the back of the neck and in the right shoulder so that the cervical spine was X-rayed. The films showed no abnormalities (Figure 4). He was discharged on the 15th day. The pain persisted and the patient developed paraesthesiae of the right index and long fingers and a feeling of weakness in the right arm. As these symptoms continued he was referred to the Orthopaedic Hospital 4 months after the accident. No neurological abnormalities were found but there was considerable limitation of movement in the cervical spine and a striking prominence of the spinous process of C7. Renewed X-ray examination now gave a good survey also in the lateral projection revealing a dislocation between C6 and C7 with displacement of almost half the width of the vertebral body and an angulation of 35° (Figure 5). Oblique views showed that the dislocation was only left-sided (Figure 6). The vertebrae had already fused by a bony bridge anteriorly and the site was stable so treatment was not felt to be indicated. However the patient was kept off work for another few months.

DISCUSSION

These two case histories constitute an alarming memento that even severe injuries to the cervical spine may be overlooked because of lack of perspicuity in the current X-ray views. As it is important to treat dislocations of the cervical spine attempts must be made to diagnose them during the acute phase. For this reason the value of the X-ray examinations will be discussed. First mention will be made of the incidence, causes and lesion mechanism in dislocations and fractures.

of the cervical spine whereas the therapeutic problems will not be discussed

Injuries to the spine are very common but only a small percentage affect the cervical part. From 1947-1951 *Trojaborg & Bryndum* (1959) found that among 1035 spinal injuries only 7 per cent were cervical. 2½ per cent of the injuries were pure dislocations and these occurred only in the cervical spine. Cervical spine lesions are most commonly localized in the area between C4 and C7. In a study of 77 forward dislocations in the area C3-T1 *Ramadier & Bomlart* (1967) found 36 to be localized between C6, C7 and T1.

In respect to the aetiology, the greatly increasing incidence in connection with motor accidents must be mentioned. *Brooks* (1933) found that 12 per cent were due to motor accidents and 50 per cent to falls. For the period 1946-1955 *Durbin* (1957) found traffic accidents to be responsible in almost 30 per cent, falls in roughly 30 per cent and diving into shallow water in 20 per cent. During the period 1956-1959 *Norton* (1962) found 70 per cent to be due motor accidents, only 15 per cent to falls and 10 per cent to diving into shallow water.

As patients involved in traffic accidents often have multiple injuries, several of which cause more striking symptoms than does a mild affection of the cervical roots, a cervical injury is particularly apt to be overlooked in these cases unless the patient is examined for this very purpose.

In an analysis of the detailed mechanism of lesion to the cervical spine *Holdsworth* (1963) found that a pure flexion trauma most often results in a wedge shaped fracture of the vertebral body without an attendant injury to the interspinous and supraspinous ligaments and that accordingly these fractures usually do not cause instability. Flexion-rotation traumas cause primary rupture of the posterior ligaments and secondarily perhaps dislocation, occasionally complicated by fracture. When the posterior ligaments have ruptured, the site is unstable. *Holdsworth* therefore pointed out the importance of a clinical examination for injury to the posterior ligaments and comparison with good X-rays. *Durbin* (1957) too mentioned the importance of the posterior ligaments to the stability. In order to demonstrate injuries to these ligaments he recommended lateral X-rays in flexion with caution and with the assistance of a doctor.

In experiments on cadavers *Beatson* (1963) found that—to produce dislocation of both articular facets—the interspinous ligament, both joint capsules, the posterior longitudinal ligament as well as the an-

nulus fibrosus had to be destroyed. He also found that displacement of less than half the width of the vertebral body was invariably connected with unilateral dislocation and that a displacement of more than half the width of the vertebral body was tantamount to bilateral dislocation. From his study it may be deduced that from the lateral X-ray views alone it can be decided whether a unilateral or bilateral dislocation is present while oblique views are required to disclose which side is dislocated in unilateral cases.

It is extremely important to differentiate between these two degrees of dislocation as soon as possible as the risk of a severe perhaps irreversible cord or root damage is far greater in bilateral than in unilateral cases (Braakman & Vincken 1967). It is by no means an invariable rule for a cervical spine injury to cause neurological symptoms; this occurs in only about half the cases. Therefore the remaining large percentage will risk neurological damage if the spinal lesion is not diagnosed and treated.

The ordinary X-ray examination of the cervical spine includes only anteroposterior and lateral views. In a cooperative patient in the erect position all the cervical vertebrae may be visualized in these views. If the patient is X-rayed in the recumbent position it is considerably more difficult to prevent superimposition by the shoulders upon the lower cervical vertebrae in the lateral exposure (Figure 7). If the patient is the victim of an accident or in pain the difficulty is increased. If furthermore there is damage to the cervical spine the patient will inevitably keep the muscles of the region so fixed that the shoulders become superimposed upon the area distal to C6 (Figures 1 and 4). This has also been demonstrated by Towne (1933) in a patient with an overlooked dislocation of C6 on C7. The AP view is of no particular value in disclosing a possible dislocation. It is true that in the case of unilateral dislocation there may be a usually very slight lateral displacement of the shadow of the spinous process of the forward dislocated vertebra but this does not apply in the case of bilateral dislocation (Figure 2). Oblique views may be of value in revealing a dislocation but it is rather difficult to assess the lower vertebrae in this projection and the exposures require quite some manipulation with the patient.

Therefore the lateral view is decisive in the acute situation but it has its weakness in respect to the lowermost vertebrae. Only Braakman & Vincken (1967) have mentioned tomography as the last resort in making a diagnosis of unilateral dislocation of C7 on T1. However as



Figure 7 Lateral view taken in the neutral re-umbent position of a healthy man with hefty shoulders. Note that only the 5 uppermost cervical vertebrae are visible

*Figure 8 Example of lateral tomography of C5 C6 C7 and T1
Same person as shown in Figure 7*

it is important not to move an injured patient more than absolutely necessary. It seems to the present author more advisable to supplement the examination immediately by a couple of tomographic views of the lowermost cervical vertebrae in the sagittal plane if the conventional laterals are not sufficiently informative (Figure 8).

CONCLUSIONS

- (1) Dislocations and fractures of the cervical spine are increasing in frequency with the increasing number of traffic accidents.
- (2) The symptoms and signs of these injuries are often slight in relation to those of other injuries that may co-exist and there need not primarily be neurological signs.
- (3) Even total dislocations between the lowermost cervical vertebrae may be overlooked because of the difficulties of radiological survey in this region in the sagittal plane.
- (4) Therefore the current projections must be supplemented by a couple of lateral tomographic exposures in the event of lacking perspicuity.
- (5) Lateral views during flexion must be obtained if there is a sus-

picion of injury to the posterior ligaments as such a lesion causes instability between the vertebrae concerned

SUMMARY

On the basis of two cases in which dislocations of C6 on C7 had been overlooked during the first stay in hospital the author reviews the incidence causes and mechanism of injuries to the cervical spine. The radiographic possibilities of diagnosing dislocations between the lower most cervical vertebrae are discussed considering that the shoulders are superimposed upon this region in ordinary laterals taken in the recumbent position especially of an injured patient who fixes the muscles in the region of the neck. It is recommended to use tomographic lateral views to secure the diagnosis immediately at the first examination.

RESUME

Sur la base de deux observations ou une dislocation entre les vertebres cervicales 6 et 7 avait passe inaperçue lors de la premiere hospitalisation il est etudie la frequence les causes et le mecanisme des lesions de la colonne cervicale. Il est discute des possibilites radiologiques pour poser le diagnostic de la luxation entre les vertebres cervicales inferieures reconnaissant le fait que les épaules jettent une ombre sur cette région sur les radiographies laterales ordinaires prises chez un malade accidente couché dont les épaules et la partie du cou sont fixes. Il est recommande d'utiliser des prises laterales tomographiques afin de s'assurer que le diagnostic puisse etre pose dès le premier examen.

ZUSAMMENFASSUNG

Auf Grundlage von zwei mitgeteilten Krankengeschichten wo eine Verrenkung zwischen C6 und C7 bei der ersten Krankenhausaufnahme übersehen worden war sieht man die Häufigkeit Ursachen und Mechanismen von Beschädigung der Halswirbelsäule durch. Die röntgenologischen Möglichkeiten einer Diagnose der Luxation zwischen den untersten Halswirbeln wird in der Erkenntnis dass die Schultern diese Region auf gewöhnlichen Seitenaufnahmen in liegender Stellung besonders bei dem beschädigten Patienten mit fixierter Schulter Halsregion verdunkeln. Man empfiehlt tomographische Seitenaufnahmen zu machen um die Diagnose gleich bei der ersten Untersuchung zu sichern.

REFERENCES

- 1 Beatson T R (1963) Fractures and dislocations of the cervical spine *J Bone Jt Surg* 45 B 21
- 2 Braakman H & Vinken P J (1967) Unilateral facet interlocking in the lower cervical spine *J Bone Jt Surg* 49 B 249
- 3 Brooks Th P (1933) Dislocations of the cervical spine *Surg Gynec Obstet* 57 712
- 4 Durbin F C (1957) Fractures dislocations of the cervical spine *J Bone Jt Surg* 39 B 93
- 5 Ebbelhøj H L (1942) Nogle tilfælde af columnarlesioner af forsikringsmæssig betydning *Nord Med* 111 569
- 6 Holdsworth F M (1963) Fractures dislocations and fracture dislocations of the spine *J Bone Jt Surg* 45 B 6
- 7 Norton W L (1962) Fractures and dislocations of the cervical spine *J Bone Jt Surg* 44 A 115
- 8 Ramadier J O & Bombart M (1964) Fractures et luxations du rachis cervical sans lésions médullaires 2 partie Lésions des 5 dernières vertèbres cervicales *Rev Chir Orthop* 50 3
- 9 Towne L B (1933) Injuries of the cervical cord and its roots following dislocation of the cervical spine *Surg Gynec Obstet* 57 783
- 10 Trojaborg V & Brøndum B (1959) Traumatisk spinallesioner I *Lægekr Læg* 121 233

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CONGENITAL FUNCTIONAL SCOLIOSIS

By

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Received 2 xii 67

Congenital functional scoliosis is a fairly rare and relatively unknown type of scoliosis. It has not previously been mentioned in Scandinavian literature. The object of this paper is to describe the appearances of congenital functional scoliosis and to elucidate the differential diagnostic problems in distinguishing it from other types of scoliosis occurring during the first year of life.

Congenital functional scoliosis is taken to mean scoliosis of unknown origin appearing during the first year of life and presumably present at birth and which is possibly due to a faulty intrauterine position. It is a characteristic of this type that it is benign and disappears spontaneously.

This benign scoliosis is called resolving infantile idiopathic scoliosis by Anglo Saxon writers. Some authors (*James 1951 Scott 1956*) divide resolving infantile idiopathic scoliosis into 2 sub groups: the resolving type and the postural type. According to *Scott (1956)* the postural type will subside slowly when the infant begins to stand, the standing posture stimulating its disappearance, whereas the resolving type does not disappear in the erect position. This latter type may even progress slightly after the infant starts standing in order to resolve spontaneously at the age of 4-5 years. One author (*Browne 1956*) calls all forms of infantile idiopathic scoliosis postural and in his opinion they all progress if untreated.

In contrast to this benign type there is the malignant one: progressive infantile idiopathic scoliosis (Figures 4 and 5), also called the progressive type, which usually sets in during the 2nd or 3rd year of life (*James 1951 Scott 1956*) although it may be observed as early as the first year. This type is characterized by steady progression throughout the period of growth. The earlier the scoliosis sets in, the greater

■ the tendency to progression This tendency is greater in boys than in girls as their growth period is longer than the girls

Other types of scoliosis that may occur during the first year of life structural scoliosis due to congenital malformations (hemivertebrae, etc.) and other types of scoliosis of known aetiology (paralytic static etc.) differ clearly from the two types mentioned above and thus fall without the scope of the present study

PRESENT MATERIAL

During the period 1936 to 1959 a total of 90 patients with congenital functional scoliosis were treated in the Orthopaedic Hospital Aarhus No distinction was made between the resolving and the postural type Out of these 90 patients only 76 are included in the material 14 being left out as the diagnosis was based exclusively upon the clinical examination without X ray films Presumably, these patients did have congenital functional scoliosis since in all cases the scoliosis remained stationary or disappeared during the period that the patients were observed in the Department Out of the remaining 76 patients 67 were seen by the author in a follow up which included clinical as well as X ray examination The average follow up period was 12 years ($5\frac{1}{2}$ – $20\frac{1}{2}$ years) The distribution by length of follow up period is shown in Table 1

Table 1 Distribution by length of follow up period

Follow up period	No. of pts
5–9 years	31
10–14 years	20
15–19 years	10
20–25 years	6

Of the remaining 9 patients 4 stated in letters that the back was straight and normal One had gone abroad and all attempts at contact have been in vain The last 4 patients failed to respond to repeated requests to present themselves for a follow up examination This makes a follow up rate of 88 per cent (67 out of 76 patients) as only those patients who had clinical and radiological examination were considered to have been sufficiently followed

Table 2 shows the age at which the scoliosis was discovered by the parents health visitor or general practitioner at the prophylactic in

fant examination as well as the age at which the patients were first seen in the Orthopaedic Hospital Aarhus

Table 2 Age distribution at detection of scoliosis and at 1st examination at the Orthopaedic Hospital Aarhus

Age in months	Scoliosis detected No of pts.	Seen for the first time in the Orthopaedic Hospital Aarhus. No of pts
1	3	0
2	7	0
3	11	3
4	12	7
5	11	8
6	9	15
7	5	13
8	2	7
9	1	3
10	4	3
11	2	8
12	0	0

The great majority of cases were detected within the first 6 months of life (53 out of 67 or 79 per cent) This is in keeping with statements in the literature *James et al* (1959) reported 4th to 10th month *Scott & Morgan* (1955) 5½ months range 1st to 9th month *Harrenstein* (1936) stated the 3rd to the 7th month but mentioned at the same time that the scoliosis is seldom observed before the 2nd month The progressive type is not diagnosed until much later according to *Scott & Morgan* (1955) at an average age of 15 months *James* (1959) reported that out of 111 scolioses of the progressive type 33 were diagnosed during the 2nd or 3rd year of life Incidentally it is apparent from the table that as a rule about 3 months elapse from the time that the scoliosis is detected until the diagnosis is definitely established

Table 3 Sex ratio and number of left and right sided scolioses

	Girls 29	Boys 33	Total 62
Right sided scoliosis	8	13	21
Left sided scoliosis	21	2	23

Table 3 gives the sex ratio which shows a considerable male preponderance viz 38/29. In this respect too the findings are in agreement with the literature. *James et al* (1959) found a ratio boys/girls of 50/27. *Lloyd Roberts & Pilcher* (1965) 67/33. Within the progressive type too *James et al* (1959) found a preponderance of boys 65/46 while *Scott & Morgan* (1955) found the condition to be equally common in both sexes.

At follow up 2 patients had complaints in the form of mild pain when overstraining the back and another 2 had more severe pain. All were found to have weak insufficient back muscles and the pain was considered of muscular nature. All 4 had a curvature of less than 10° 3 of them of less than 5°.

In 9 cases there was clinically very slight scoliosis merely discernible in II of the cases. In 18 cases there was torsion prominence just discernible in 9 while the other 9 had mild but distinct torsion.

Table 3 shows moreover that left sided scoliosis was more than twice as common as right sided. There was no sex difference in this respect. *James et al* (1959) as well as *Scott & Morgan* (1955) also found left sided scolioses to be more common and this applies also the progressive type.

Table 4 Angle of scoliosis at 1st examination and at follow up

Angle	When first seen No of pts	At follow up No of pts
0-5	0	47
6-10	15	17
11-15	25	3
16-20	90	0
21-25	4	0
26-30	3	0
	67	67

The degree of scoliosis was measured on the primary X-ray films as well as on the follow up films. The curve was measured as the angle between the upper plate of the cranial and the lower plate of the caudal vertebra involved in the torsion. The primary angle averaged 15° (7-29°). At follow up the corresponding angle was less than 5° in 47 patients and as is apparent from Table 4 did not exceed 15° in any case.

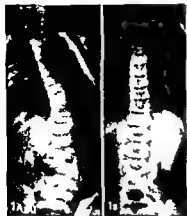


Figure 1 Congenital functional scoliosis (male) A Age 5½ months B Age 6 years

Figure 2 Congenital functional scoliosis (male) A Age 5 months B Age 14 months (not included in the material)

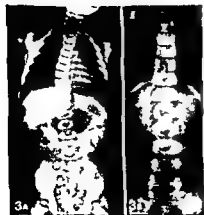
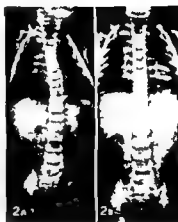


Figure 3 Congenital functional scoliosis (with compensatory curvature) (male) A Age 8 months B Age 7 years

Radiographically most patients showed long soft C shaped single curvatures without compensatory curves (Figures 1 and 2) In one case however there was a hint of compensation (Figure 3) At the primary physical examination 55 patients had exhibited slight posterior torsion of the ribs on the same side as the convexity of the scoliosis In the remaining 12 cases no mention is made of a torsion prominence The number of vertebrae involved in the curve ranged from 8 to 11 average 9 (8.6) The greater part of the curvatures affected the thoracic spine the peak of the convexity corresponding to the 9th or 10th thoracic vertebra (T_9 - T_{10}) Table 5 illustrates the site and extent of the scolioses In more than half viz in 38 out of 67 patients or in 57 per cent of the scolioses the uppermost vertebra was T_5 - T_7 and the lowermost L_1 - L_2

Table 5 Extent of scoliosis Uppermost (vertical column) and lowermost (horizontal line) involved vertebra

	T_1	L_1	L	L_5	Total
T_4	3	4	3		10
T_5	3	9	8	2	22
T_6	1	8	7	1	17
T_7		1	6		7
T_8		3	4	1	8
T_9			1	2	3

James *et al* (1959) found the majority of curvatures to be 11-20°, Scott & Morgan (1955) below 20°. Moreover the latter found torsion to be minimal while in the progressive type the curvature was seldom below 20° and the torsion more pronounced already at the first examination In the progressive type moreover there is compensatory curvature (Figures 4 and 5) which is rarely present in the functional type (Figures 1 and 2) Scott & Morgan (1955) also found the progressive types to involve fewer vertebrae than the functional type 3-8 vertebrae in the progressive as compared with 5-10 in the functional type

During the period 1936-1954 44 cases of congenital functional scoliosis were diagnosed in the Orthopaedic Hospital Aarhus as compared with 4 cases of the progressive type This means a frequency of progressive scoliosis of 13 per cent but no doubt this is too high as some of the functional cases are never seen by an orthopaedic surgeon or



Figure 4 Infantile progressive idiopathic scoliosis (female)

A Age 11 months B Age 19 months C Age 13 years

will simply be overlooked and thus never be recorded whereas the progressive cases are bound to be sent for treatment in an orthopaedic department. *Lloyd Roberts & Pulcher (1963)* reported a frequency of 8 per cent.

Prior to 1955 12 of the most severe cases of congenital functional scoliosis were treated in a plaster or celastic bed. Two patients were treated in a corrective bed the trunk being bent to the side of the convexity of the scoliosis. Patients seen after 1955 have received no treatment at all.

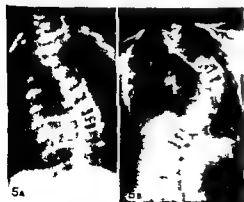


Figure 5 Infantile progressive idiopathic scoliosis (male) A Age 10 months B Age 10 years

DIAGNOSTIC CRITERIA

The typical patient with congenital functional scoliosis is a healthy normal looking boy of 6-7 months in whom the parents have noted a curvature of the spine stationary through a couple of months. The thoracic spine shows a long very mild most often left sided scoliosis with slight torsion prominence of the ribs but no compensatory curvature. This scoliosis does not disappear when the baby is held suspended by the arms. X rays reveal a long soft C shaped single curve with slight torsion and no compensation. The apex of the scoliosis is at T_9 or T_{10} and it involves about 9 vertebrae which exhibit no congenital malformations. In most cases the scoliosis is localized within the area of T_8 -L.

The main problem is to distinguish the benign type of congenital functional scoliosis from malignant infantile idiopathic scoliosis as early as possible. During the first year of life it is usually impossible to decide with certainty whether a scoliosis is going to progress or to disappear. The functional type involves a larger number of vertebrae and has no compensatory curvature. Besides it shows a lesser angle and less torsion and it sets in at an earlier age. The progressive type is far less common than the functional type.

Only close observation can afford the answer. Therefore the congenital functional scolioses have to be followed until they have disappeared or have remained stationary and very mild for a long time. As a rule this cannot be decided until the age of 2 years.

SUMMARY

The most important types of scoliosis which may occur during the first year of life are briefly reviewed. A follow up on a material of 67 patients with congenital functional scoliosis is reported. Average follow up period was 12 years. At follow up practically all the scolioses had straightened spontaneously. The appearances of congenital functional scoliosis are described and the most important differential diagnostic criteria from infantile progressive idiopathic scoliosis are discussed. It is concluded that a distinction between the two types can be made only by frequent examinations during the first years of life.

RESUME

Les types les plus importants de scolioses qui peuvent se produire pendant les premières années de la vie sont passés en revue. L'obser-

vation de 67 malades atteints de scoliose congenitale fonctionnelle est exposes La periode moyenne d'observation a ete de 12 ans On a constate au cours de ces observations que pratiquement toutes les scolioses se sont redressees spontanement Les aspects de la scoliose fonctionnelle congenitale sont decrits et il est discute des criteres les plus importants du diagnostic differentiel de la scoliose idiopathique infantile progressive Il est conclu que seuls des examens frequents durant la premiere annee de la vie permettent d'elablr une distinction nelle entre ces deux types de maladies

ZUSAMMENFASSUNG

Die wichtigsten Typen von Skoliose welche im ersten Lebensjahre auftreten können werden in kurze durchgegangen Eine Nachuntersuchung eines Materiales von 67 Patienten mit kongenitaler funktioneller Skoliose wird vorgelegt Die durchschnittliche Beobachtungszeit war 12 Jahre Bei der Nachuntersuchung hatten sich fast alle Skoliosen von selbst ausgerichtet

Das Aussehen der kongenitalen funktionellen Skoliose wird beschrieben und die wichtigsten differential diagnostischen Unterschiede von der infantilen progressiven idiopathischen Skoliose werden besprochen Man schliesst dass eine Unterscheidung beider Arten nur mittels häufiger Untersuchung in den ersten Lebensjahren gemacht werden kann

REFERENCES

- 1 Browne D (1936) Congenital Postural Scoliosis *Proc roy Soc Med* 49 395
- 2 Harrenstein R J (1936) Sur la scoliose des neurossons et des jeunes enfants *Revue d'Orthopedie* 43 annee serie 3 23 99
- 3 James J I P (1951) Two Curve Patterns in Idiopathic Structural Scoliosis *J Bone Jt Surg* 33B 399
- 4 James J I P Lloyd Roberts G C. & Pilcher M F (1959) Infantile Structural Scoliosis *J Bone Jt Surg* 41B 719
- 5 Lloyd Roberts G C. & Pilcher M F (1965) Structural Idiopathic Scoliosis in Infancy *J Bone Jt Surg* 47B 590
- 6 Scott J C. (1956) Differential diagnosis of Infantile Scoliosis *Proc roy Soc Med* 49 398
- 7 Scott J C. (1959) Resolving Scoliosis *J Bone Jt Surg* 41B 105
- 8 Scott J C. & Morgan T H (1955) The natural History and Prognosis of Infantile Idiopathic Scoliosis *J Bone Jt Surg* 37B 400

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LONG TERM PROGNOSIS IN IDIOPATHIC SCOLIOSIS

By

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Received 21 68

The prognosis in idiopathic scoliosis has chiefly been discussed in terms of the possibility of forecasting the progress of a curvature observed at the onset of the disease. It is of course understandable that the orthopedic surgeon should concentrate on patients whose age makes them particularly susceptible to progression of the scoliosis and that most attention should then be paid to the opportunities for active therapy. At the same time little is known about the fate of scoliotic patients after they have left the orthopedic surgeon's immediate field of interest. There are a number of general statements (*e.g.* Kleinberg 1951, Vargel Lange 1962) to the effect that patients with severe scoliosis generally die before the age of 45-50, the deformation of the thorax impairing the heart-lung function and thereby resulting in an increased mortality. Chapman *et al.* (1939) in a group mainly composed of paralytic scolioses even give a worse prognosis with an average death age of 30 years. Sulzer (1958) on the other hand reports that in an autopsy material the average death ages in kypho-scoliotic individuals were in agreement with those of the general population of Switzerland. The material was however rather mixed and even included osteoporotic changes of the spine in old patients. Thus it would seem that no systematic study has been published of the long term prognosis in a pure group of idiopathic scoliosis.

The present study on a group of patients with an observation time of up to 50 years contains an analysis of the vital prognosis in idiopathic scoliosis and an account of the social and socio-medical function of these patients. A preliminary report has already been published (Nilsson & Lundgren 1964).

MATERIAL

The study comprises a group of patients with idiopathic scoliosis who came to the Orthopaedic Clinic in Stockholm in the period 1/7 1913-30/6 1918 i.e. the first five years after the Clinic opened.

The concept of idiopathic scoliosis does not appear as a diagnosis in the case reports from that time. The earliest instance of this terminology that we were able to find in the literature dated from 1923 (Kleinberg). The Orthopaedic Clinic's records of diagnoses from the period covered by this study contain a variety of terms including scoliosis rachitica scoliosis congenita scoliosis habitus scoliosis essentialis and insufficientia vertebrae; moreover these diagnoses are usually accompanied by a question mark to denote the examining physician's uncertainty about the etiology.

Some importance used to be attached to rickets as a cause of progressive scoliosis but this has been refuted by more recent investigations (e.g. Brunk 1951). Nearly all the present case reports include an ordinary full length photograph of the patient none of which display any external signs of deformities that might suggest rickets. It is thus most unlikely that any patient with rickets has been included in this investigation.

The available case reports contain very little if any information about the duration of the scoliosis and consequently the present cases may include an occasional instance of congenital scoliosis e.g. due to vertebral malformation. This source of error cannot be very large however since the maximum incidence of congenital scoliosis is reported to be 5 per cent (Kleinberg 1951).

The photographs and in some cases X-ray pictures show that the other diagnostic terms exemplified above refer to structural not functional scolioses.

The records from the period covered by this study include a large number of paralytic scolioses arising from polio. Since the sequelae of polio were a central orthopaedic problem at that time we have accepted the diagnosis of paralytic scoliosis and such cases have been excluded.

Table 1 Distribution of patients by year of admission

	1913	1914	1915	1916	1917	1918	Total
M	2	1	4	8	9	1	25
F	8	19	19	17	17	8	88
M + F	10	20	23	25	26	9	113

(In this and the following tables M = males F = females)

With these criteria we have arrived at a group of patients whose diagnosis in modern terms would be idiopathic scoliosis. The patients either received no treatment or else they were prescribed physiotherapy and/or a supporting brace. No active attempts were made to correct the scoliosis by conservative or surgical means. From the modern point of view the material may be regarded as a group of untreated patients with idiopathic scoliosis.

The composition of the material is presented in Table 1 which also shows the number of new cases per year during the period of the study. The total material comprises 113 patients: 88 female and 25 male. The female incidence is thus 78 per cent which is in good agreement with the recognized sex difference in idiopathic scoliosis (Lindeman 1958) namely that rather more than three times as many females contract the disease as males.

Table 2. Distribution by age at admission

Age at admission	M	F	M + F
7-9	4	6	10
10-14	4	36	40
15-19	11	33	44
20-24	4	7	11
25-29	1	4	5
30-34	1	2	3
Total	25	88	113

The distribution by age at the time of admission is given in Table 2. (The ages represent the difference between the year of admission and the year of birth.) The mean age on admission for the total material is 15.9 years, while for the males it is 16.7 years and for the females 15.6 years (see also Table 3). These average ages seem to be higher than they are today, no doubt because the improved medical control of school children now results in an earlier orthopaedic assessment of any back trouble. If instead the mean age on admission is calculated only for those patients in whom the scoliosis had not yet become stationary, the result is 13.7 years for the females and 12.5 years for the males (assuming that skeletal growth and hence the progression of the scoliosis had ceased in women of 17 or more and in men of 18 or more so that these cases are excluded). This indicates that a large proportion of the patients with idiopathic scoliosis in the period 1913-1918 were observed during the progressive stage in puberty when they were roughly the same age as the patients encountered today.

VITAL STATISTICS

Inquiries were made to find out whether or not the patients were still alive at the time of this study. In the case of those who had died, the year and the cause of death were ascertained from the parish registry office. In most cases it was possible to obtain the case reports on these patients, last hospitalization and thereby confirm the reported cause of death. Further verification was obtained in many cases from the autopsy report. The patients have been followed up to the middle of 1963 which thus constitutes the end of the observation period for the living.

individuals. The reported ages were calculated as the difference between the last year of observation (1963 or the year of death) and the year of birth. Eleven of the 113 patients could not be traced because the personal data in the records were too scanty to permit re-identification in the ordinary population register.

The distribution between living and dead patients is given in Table 3. Of all those who could be traced, 56 were alive and 46 had died at the time of this study, the corresponding figures for the 25 males being 10 alive and 12 dead (3 not traced) and for the 88 females, 46 alive and 34 dead (8 not traced).

Table 3 Distribution by living, dead and not followed

	M	F	M + F
Living 1963	10	46	56
Dead	12	34	46
Not followed	3	8	11
Total	25	88	113

Table 4 Mean age of living and dead patients

	Living 1963	
	No.	Mean age
M	10	60.0
F	46	62.6
M + F	56	62.1
	Dead	
	No.	Mean age
M	12	51.9
F	34	44.8
M + F	46	46.6

The mean ages of the living and the dead patients are given in Table 4. There is a considerable difference between these groups, the mean age for the former being 62.1 years and for the latter 46.6 years. In the dead group, the mean age of the women at the time of death, 44.8 years, is definitely lower than that for the men, 51.9 years.

The mean age of all the patients at the time of their first visit to the Clinic is given in Table 5. Those who have died were older at their first

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The distribution by age at the time of admission is given in Table 2. (The ages represent the difference between the year of admission and the year of birth.) The mean age on admission for the total material is 15.9 years while for the males it is 16.7 years and for the females 15.6 years (see also Table 5). These average ages seem to be higher than they are today, no doubt because the improved medical control of school children now results in an earlier orthopaedic assessment of any back trouble. If instead the mean age on admission is calculated only for those patients in whom the scoliosis had not yet become stationary, the result is 13.2 years for the females and 12.5 years for the males (assuming that skeletal growth and hence the progression of the scoliosis had ceased in women of 17 or more and in men of 18 or more so that these cases are excluded). This indicates that a large proportion of the patients with idiopathic scoliosis in the period 1913-1918 were observed during the progressive stage in puberty when they were roughly the same age as the patients encountered today.

VITAL STATISTICS

Inquiries were made to find out whether or not the patients were still alive at the time of this study. In the case of those who had died the year and the cause of death were ascertained from the parish registry office. In most cases it was possible to obtain the case reports on these patients last hospitalization and thereby confirm the reported cause of death. Further verification was obtained in many cases from the autopsy report. The patients have been followed up to the middle of 1963 which thus constitutes the end of the observation period for the living.

PROGNOSIS IN IDIOPATHY

Table 7 Number of observed (O) and expected (E) deaths

	M		F	
	O	E	O	E
Period				
1913-20		0.6	1	1
1921-30		0.9	1	1.1
1931-40		0.9	2	1.1
1941-50	9	0.8	11	1.1
1951-60	2	1.1	1	1
1961-63	1	0.4	1	1
Age				
7-19		0.4	1	1
20-34		1.4	6	1.1
35-49	5	1.3	12	1.1
50-64	7	1.6	11	1.1
65		0.0	2	1.1
7-44	2	0.6	1	1.1
45-	10	2.1	21	1.1
Total	12	4.7	34	1.1

Table 8 Mortality ratio (O/E)

Age	M			F	
	O	E	O/E	O	E
7-44	1	2.6	0.8	13	8.6
45-	10	2.1	4.8	21	7.0
Total	12	4.7	2.5	34	15.6

Table 7 presents a comparison between observed and the number expected. The data is broken down by decade as well as by age. The calculations for the Swedish population. It will be considerably higher than expected, particularly in the period 1941-50, with 20 deaths compared with only 3.7. As far as age is concerned, that mortality is higher than expected, 2.06 expected.

The relationship between observed and expected is expressed as a mortality ratio (Table 8).

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group over 45 years of age. For the men in this group the mortality ratio is extremely high 4.8 but here it should be noted that the mortality for men is about 20 per cent higher in Stockholm than in the rest of Sweden (Larsson 1965) to some extent therefore this high figure may reflect the fact that 11 of the 25 males were resident in the city or county of Stockholm at the time of their first visit to the Clinic. The mortality ratio for all the patients aged 45 or more is 3.2 while that for the entire material is 2.2. In other words the mortality in idiopathic scoliosis in this material is more than twice as high as in the general population.

Table 9 Distribution by cause of death

Cause of death	Sex		Age at death									
	M	F	M					F				
Pulmonary disease	1	11	53					18 18 19 20 24 33				
								39 43 45 45 54				
Cardiac incompensation	7	9	39 41 47 48 51 51 54					27 33 38 41 46 47				
								48 54 56				
Arteriosclerosis	3	6	62 63 64					55 62 64 64 67 66				
Tumour	1	4	47					33 44 45 57				
Other		4						48 50 50 57				
Total	12	34										

The causes of death are reported in Table 9. Lung disease comprises pulmonary tuberculosis and pneumonia. Cardiac incompensation refers to the patients who died in right heart failure. In several of these cases the death certificate even mentions the term kyphoscoliotic heart. Under arteriosclerosis the causes of death were cerebral haemorrhagia and cardiosclerosis. Only malignant tumors are included under tumor. Other causes of death include suicide and delirium.

Cardiac or pulmonary disease accounted for about 60 per cent of the deaths. The age at death is also given in Table 9 which shows that 13 of the 28 cases of heart or lung disease died before the age of 45.

SOCIAL AND SOCIO-MEDICAL ASPECTS

Besides suffering cosmetically patients with idiopathic scoliosis have a reduced physical work capacity particularly in severe cases. The

marriage rate for the females in this material (excluding those not traced) has been taken as a measure of the social function. About 76 per cent are unmarried (Table 10). The proportion of married women is higher among the living patients which might be expected since they have had more time in which to find a partner. Nevertheless the figures show that an extremely large proportion of women with idiopathic scoliosis do not marry.

Table 10 Distribution of followed women by marital status

F	No	Unmarried	
		No	%
Living	46	31	67
Dead	34	30	88
Total	80	61	76

Table 11 Orthopaedic and disablement status for 50 living patients (see text)

Mean age living	67.1 years
Back symptoms	90 %
Disablement pension for scoliosis	30 %
Disabled but no pension	17 %

A questionnaire was distributed to all the living patients asking about their work function and any subjective back trouble. Answers were received from 50 out of 56. Back symptoms were reported by 90 per cent (Table 12) mostly in the form of a feeling of tiredness or pains in the thoracic or lumbar spine on exertion. Many of the patients had used some type of corset most of their lives. Of those who answered 30 per cent stated that they had received a disablement pension for their back trouble while a further 17 per cent considered that they were unable to work and had apparently managed by living with their parents or relatives most of their lives. Altogether therefore 47 per cent of the living patients were disabled.

CONCLUSIONS

The study shows that there is an abnormally high mortality in idiopathic scoliosis. The average mortality among the 102 patients who could be traced is twice that in the normal population. The mortality appears to be highest after the age of 40. However since the majority

of the 11 patients who could not be traced and who were therefore excluded from the mortality calculations probably died in the early part of the observation period it is possible that the actual mortality before the age of 45 is higher than indicated by the present figures. Cardiac or pulmonary disease was the cause of death in 60 per cent of the patients who died.

Idiopathic scoliosis may also involve a social and sociomedical handicap. The cosmetic deformity is reflected in an extremely high proportion of unmarried women. Imbalance in the spinal column is evident from the markedly high incidence of subjective back trouble. An indication of the effect on the physical work capacity is provided by the finding that almost half of the living patients are unable to work.

These circumstances must be borne in mind when assessing the seriousness of a newly discovered case of idiopathic scoliosis.

SUMMARY

113 cases of idiopathic scoliosis (88 females 25 males) first noted in the period 1913-18 were followed up to 1963. The material presents a marked hypermortality with a mortality ratio of 2.2. Cardiac or pulmonary disease was the cause of death in 60 per cent of the individuals who died. The sociomedical effects of scoliosis are reflected in the very high proportion of the women who have not married as well as in the high percentage of the living individuals who are unable to work.

ACKNOWLEDGEMENT

Mr Tage Larsson MD FL Chairman of the Medical Research Council of the Swedish Life Offices has given us kind and valuable advice in the statistical approach for which we are most grateful.

RESUME

113 cas de scoliose idiopathique (88 femmes 25 hommes) observés pour la 1^{re} fois entre 1913 et 1918 ont été suivis jusqu'en 1963.

L'échantillon présente une hypermortalité marquée avec un rapport de mortalité de 2.2.

Les maladies cardiaques ou pulmonaires ont été les causes de la mort de 60 pour cent des individus décédés.

Les effets sociaux médicaux de la scoliose se traduisent par une proportion élevée de femmes qui ne se sont pas mariées ainsi que par un haut pourcentage d'individus vivants incapables de travailler.

ZUSAMMENFASSUNG

113 Fälle von idiopathischer Skoliose (88 weibliche 25 männliche) erstmalig registriert während der Periode 1913–1918 wurden bis zu 1963 beobachtet. Dieses Material zeigt eine markante Hypermortalität mit der Mortalitätsratio von 2.2. Herz- und Lungenkrankheiten waren die Todesursache in 60 Prozent der Todesfälle. Die sozialmedizinische Bedeutung der Skoliose tritt in der hohen Zahl der unverheirateten Frauen sowie in der hohen Zahl der nicht arbeitsfähigen Individuen hervor.

REFERENCES

- Brunk M (1951) The importance of rickets in childhood as a cause of scoliosis in adult age *Acta orthop scand* Suppl 9
- Chapman F M, Dill D B & Cravhuel A (1939) The decrease in functional capacity of the lungs and heart resulting from deformities of the chest: pulmonocardiac failure *Medicine* 18 167
- Kleinberg S (1972) The operative treatment of scoliosis *Arch Surg* 5 631
- Kleinberg S (1951) Scoliosis Williams and Wilkins Comp. Baltimore
- Lange Margret (1967) Internistische Beobachtungen bei Skoliosen. *Verh dtsch orthop Ges* 50 47
- Larsson T (1965) Mortality in Sweden *Suppl Acta genet et statist med* Vol 15
- Lindemann K. (1958) Skoliosen. In Handbuch der Orthopädie C Thieme Stuttgart.
- Nilsson U & Lundgren K. D. (1964) Långtidsprognosen vid idiopatisk scolios *Nord Med* 72 1088
- Sulzer U J (1958) Zur Klinik und pathologischen Anatomie der Kyphoscoliose mit besonderer Berücksichtigung der Lebenserwartung *Cardiologia* 32 231

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A LONG TERM FOLLOW UP STUDY OF NON TREATED SCOLIOSIS

By

ALF NACHEMSON

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It is a well known fact that severe lateral curvature of the spine causes respiratory disturbances and an overload of the lung and the heart (1 2 5 9 10 17 20). Reports have been published on the effect in the respiratory volume in scoliotic patients and it has been said that curvatures about 50 to 60 will cause considerable lowering of the vital capacity in these patients (6 7 8 14). Other reports have been published on the indirect effect on the heart (2 5 10). Thus we know that a lateral curvature will decrease the vital capacity but very few papers have been published on the life expectancy in these patients.

In large autopsy materials severe scolioses have been found in 11.5 per cent (20). In such studies the mean age at death (30-50 years) for corpses with lateral curvatures of their spines has been found to be lower than for the average population especially if these curves were known to have started adolescence (5 17 20). In a communication of a 50 year follow up on 113 cases of idiopathic scolioses who were seen 1913-1918 in Stockholm Nilsson & Lundgren (15) reported a 100 per cent increase in mortality compared to people born in the year 1900.

Previous follow up studies have been concerned mainly with the result of different types of non operative and operative treatment. These however cover only a limited period of time up to the end of the growth period of the patients (3 4 11 13 16 18 19 22). While the results of non operative treatment have been very discouraging with the exception of the Milwaukee brace (3 4) opinions differ with regard to the result of the operative treatment. It is obvious however from the latest reports that more and more drastic measures have been adopted in order to achieve and secure a straight spine (11 12 19 22). Wedge resections of vertebral bodies and different kinds of internal

supports have been advocated. Today the operative treatment of scoliosis is often of great magnitude and mortality has been reported (11).

It would therefore be of interest to have a long term follow up on untreated scoliotic patients with regard to life expectancy and to working capacity. This of course is regardless of the cosmetic disability which always exists.

MATERIAL

This material consists of those patients with a scoliosis who looked for medical advice to the Department of Orthopaedic Surgery in Gothenburg during the years 1907 to 1936.

During these years all patients in the western part of Sweden covering a population of about 1 900 000 people were sent here for orthopaedic advice and it can certainly be said that most of the patients with a lateral curvature of the spine of some magnitude in this region were seen. However at that time no treatment was advised except occasional stretch exercises.

From the available charts it is impossible to say how bad the curves were but in about 50 per cent of the cases photographs of the back were taken. No roentgenograms were made. The possible etiology of the scoliosis and the age when the curve was first noticed are also listed. The curve was regarded as congenital if it was noticed under the age of 1 year. With regard to the purpose of this paper it is considered of relatively minor importance whether it was a definite congenital curve or a structural infantile scoliosis. The miscellaneous group consists of two cases of scoliosis due to tuberculosis of the spine, one case of neuro fibromatosis and one case of thoracogenic curve.

Table 1. Etiology, sex and direction of main curve in the thoracic or thoracolumbar region in 130 patients.

Curve convex to	Idiopathic		Rachitogenic		Polymelic		Congenital		Miscellaneous	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Right	12	40	3	10	6	10	3	3	1	—
Left	—	7	7	8	—	5	7	2	11	2
	52		20		23		15		5	

In this report only those patients were followed who during the above mentioned period of time were under the age of 25 years at their first visit. A total of 130 patients fall into this category. It was not possible to differentiate between either the localization or the exact extent of the curves.

It is seen from Table 1 that 3 per cent were women and 97 per cent men. The composition of the material with regard to the different etiological groups, sex and direction of the curve does not differ much from other materials (18, 19, 20, 21).

The average age of the patients at their first visit was 14 years (12-25 years).

Table II Causes of death 20 patients out of 117

Age of patient when first seen	Sex	Type of curve according to orig records	Age at death	Main cause of death
9	♀	idiopathic right sided thoracic	42	kyphoscoliotic cardiopathy with cor pulmonale
12	♀	poliomyel right sided thoracic	44	kyphoscoliotic cardiopathy with cor pulmonale
25	♂	idiopathic right sided thoracic	44	kyphoscoliotic cardiopathy with cor pulmonale
25	♀	rachitog right sided thoracic	36	kyphoscoliotic cardiopathy with cor pulmonale
16	♀	the spondylitic left sided thoracic	16	Nephritis
17	♀	idiopathic right sided thoracic	43	Sulicide
16	♀	polio right sided thoracic	44	kyphoscoliotic cardiopathy with cor pulmonale
9	♀	rachitog right sided thoracic	43	kyphoscoliotic cardiopathy with cor pulmonale
9	♀	congenital right sided thoracic	70	kyphoscoliotic cardiopathy with cor pulmonale
15	♂	rachitog right sided thoracic	24	kyphoscoliotic cardiopathy with cor pulmonale
12	♀	rachitog left sided thoracic	40	kyphoscoliotic cardiopathy with cor pulmonale
13	♀	idiopathic left sided thoracic	24	Uremia
20	♂	polio right sided thoracic	34	kyphoscoliotic cardiopathy with cor pulmonale
11	♀	congenital left sided cervicodorsal	44	kyphoscoliotic cardiopathy with cor pulmonale

Table 2 (cont.)

Age of patient when first seen	Sex	Type of curve according to orig records	Age at death	Main cause of death
1	♀	congenital left sided thoracic	23	kyphoscoliotic cardiopathy with cor pulmonale
17	♀	neurogen left sided thoracic	47	Carcinoma of the uterus
20	♂	rachitic right sided thoracic	40	kyphoscoliotic cardiopathy with cor pulmonale
15	♀	idiopathic right sided thoracic	30	kyphoscoliotic cardiopathy with cor pulmonale
16	♀	congenital right sided thoracic	46	kyphoscoliotic cardiopathy with cor pulmonale
19	♀	polio left sided thoracic	8	kyphoscoliotic cardiopathy with cor pulmonale

RESULT OF THE FOLLOW UP IN 1966

It was possible to trace a total of 117 patients. Of these 20 were dead as listed in Table 2. It can be seen that 16 of these died from cardio-pulmonary diseases probably related to the lateral curvature of the spine.

A statistical analysis was made to show the number of deaths in an average Swedish population with the same age and sex distribution as the present material. The number of expected deaths in such a material was 10.4.

The observed number in this material was 20. This obviously is a statistically significant increase.

When the material was divided into etiological groups as in Table 3 it was also found that the number of deaths in the two groups congenital and miscellaneous were significantly raised in comparison with the idiopathic group.

Those 97 patients that were still alive and were located all replied to a questionnaire where they had to state

4 Of those engaged in full time work 48 had some kind of light occupation while 21 were in medium hard work No one was occupied in hard manual labour

5 Pain in the back was a relatively constant finding in 39 of the 97 patients and this symptom was found in about the same percentage in all the different etiological groups

II Only 24 patients used a brace or corset of any kind

DISCUSSION

This follow up study on 117 patients with lateral curvature of the spine shows that the deformity irrespective of what its cause might be is a very serious one It confirms that a severe scoliosis causes grave disturbance in the function of the lungs and the heart

The original material consisted of 130 patients but 13 of these could not be traced With regard to age sex and type of scoliosis this group did not differ from the rest of the material and the outcome of these patients with all probability will not alter the conclusions presented

From the results it is shown that this group of patients suffered from nearly 100 per cent increased mortality as compared to the general population It should be emphasized that the present material also comprises a number of less severe curves but as previously mentioned it was impossible from the available charts to draw any conclusion regarding the severity of the curve since no roentgenograms were made It can only be said that in the group of 97 surviving patients contracted the curve was noted to be minor in 12 In none of the charts of the deceased could this statement be found Thus with all probability the mortality rate of a severe scoliosis (80° or more) is well over 100 per cent compared to the average population

This is also supported by the fact that the highest mortality rate was found in the groups congenital and miscellaneous Such curves are known to progress to very severe ones in most cases (13 19) Table 3

The decreased ability to perform ordinary work of these patients is seen from the number claiming disability compensation 24 of the 28 patients not working blamed their incapacity on their scoliosis or related diseases

A comparison can be made with an investigation performed in 1963 on 973 men in Goteborg born in the year 1913 Of these 23 (2.3 per cent) claimed disability compensation 13 of those on psychiatric grounds Of the remaining 950 men one third was occupied in heavy labour one third in medium hard work and one third had some kind of collar work (21)

In the present group of 97 patients that was followed there were 32 men who were seen or contacted at the average age of 48 years. Of these 7 could not perform any work at all (22 per cent) while 15 (60 per cent) were engaged in collar work and 10 (40 per cent) had a medium hard work. No one was occupied in heavy labour.

Thus it is clear that lateral curvature of the spine also reduces the working capacity to a very great extent.

Pain in the back was a relatively constant symptom in 39 of the 97 patients followed. This is probably due to the severe degree of osteoarthritic changes that always will occur in these patients. Two patients reported constant severe disabling pain.

Only 25 of the 97 patients reported a constant use of brace or corset in spite of the fact that these are given to the patients at no expense in Sweden.

The follow up results obtained in the twelve patients who were examined by the author are included in the above presentation. In three of these patients roentgenograms revealed a primary lumbar curve.

It is known that those with low thoracolumbar or lumbar curves will be less disabled from cardio pulmonary insufficiency (7-20). Unfortunately it was not possible to differentiate the exact extent and site of the primary curve from the charts available. It is probable however that in the number of patients surviving without disability a relatively high proportion of primary lumbar curves is to be found.

It is thus likely that the increased rate of mortality in patients with a cervico dorsal or dorsal scoliosis of some severity will be higher than the 100 per cent found in this general material.

SUMMARY

This long term follow up of non treated scoliotic patients was done to evaluate the disability and eventual increased mortality rate that could be suspected from our knowledge of the pulmonary and cardiac distress that develops in some of these patients. Of the 130 patients who were seen in the department from 1927-1936 117 could be traced. Of these 20 were deceased. In a similar group of the general population the number of expected deaths were 10.4. 16 of the patients in this material died from kyphoscoliotic cardiopathy with cor pulmonale.

With regard to the etiology of the lateral curve the congenital thoracogenic and neurogenic ones were found to have a worse prognosis than the idiopathic rachitogenic and poliomyelitic scoliosis.

4 Of those engaged in full time work 48 had some kind of light occupation while 21 were in medium hard work No one was occupied in hard manual labour

5 Pain in the back was a relatively constant finding in 39 of the 97 patients and this symptom was found in about the same percentage in all the different etiological groups

6 Only 24 patients used a brace or corset of any kind

DISCUSSION

This follow up study on 117 patients with lateral curvature of the spine shows that the deformity irrespective of what its cause might be is a very serious one It confirms that a severe scoliosis causes grave disturbance in the function of the lungs and the heart

The original material consisted of 130 patients but 13 of these could not be traced With regard to age sex and type of scoliosis this group did not differ from the rest of the material and the outcome of these patients with all probability will not alter the conclusions presented

From the results it is shown that this group of patients suffered from nearly 100 per cent increased mortality as compared to the general population It should be emphasised that the present material also comprises a number of less severe curves but as previously mentioned it was impossible from the available charts to draw any conclusion regarding the severity of the curve since no roentgenograms were made It can only be said that in the group of 97 surviving patients contacted the curve was noted to be minor in 12 In none of the charts of the deceased could this statement be found Thus with all probability the mortality rate of a severe scoliosis (80 or more) is well over 100 per cent compared to the average population

This is also supported by the fact that the highest mortality rate was found in the groups congenital and miscellaneous Such curves are known to progress to very severe ones in most cases (13 19) Table 3

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In the present group of 97 patients that was followed 7 men who were seen or contacted at the average age of 47. 7 could not perform any work at all (22 per cent) were engaged in collar work and 10 (40 per cent) were engaged in heavy labour.

Thus it is clear that lateral curvature of the spine has a very great effect on working capacity to a very great extent.

Pain in the back was a relatively constant symptom in all patients followed. This is probably due to the degenerative and arthritic changes that always will occur in these patients. It is reported constant severe disabling pain.

Only 20 of the 97 patients reported a constant pain in spite of the fact that these are given to the patients in Sweden.

The follow up results obtained in the twelve patients examined by the author are included in the above. Of these patients roentgenograms revealed a primary curve.

It is known that those with low thoracolumbar curves are less disabled from cardio pulmonary insufficiency. However, it was not possible to differentiate the primary curve from the charts available. It is found that in the number of patients surviving with a high proportion of primary lumbar curves.

It is thus likely that the increased rate of cervico dorsal or dorsal scoliosis of some of the 100 per cent found in this general material.

SUMMARY

This long term follow up of non treated scoliosis was made to evaluate the disability and eventual mortality. It is suspected from our knowledge of the disease that develops in some of these patients. In the department from 1927-1950 20 were deceased. In a similar group of 100 patients the number of expected deaths were 10. It is found that 10 died from kyphoscoliotic cardiopathy. With regard to the etiology of scoliosis, the racogenic and neurogenic ones are more common than the idiopathic. It is found that the

In 39 out of 97 patients pain in the back was noted as a commonly occurring symptom

RÉSUMÉ

Cet examen à long terme chez des malades scoliotiques qui n'ont pas subi de traitement a été effectué pour juger de leur incapacité de travail et éventuellement du taux plus élevé de mortalité que l'on pouvait soupçonner en parlant des connaissances que nous avons des troubles pulmonaires et cardiaques qui se développent chez certains de ces malades. Il a été possible de retrouver la trace de 117 des 130 malades observés dans notre Département entre 1927 et 1936. 20 d'entre eux étaient décédés. Dans un groupe correspondant de la population générale le nombre des décès aurait vraisemblablement été de 10-16 des malades appartenant à ce matériel sont décédés de cardiopathie cyphoscoliotique avec cœur pulmonaire. En ce qui concerne la capacité de travail il a été constaté que celle-ci était fortement diminuée par comparaison avec la population générale.

Par rapport à l'étiologie de la courbure latérale on a constaté que les formes congénitales thoracogéniques et neurogéniques ont un pronostic plus favorable que les scolioses idiopathiques rachitogéniques et polymyéliques.

Chez 39 des 97 malades des douleurs dorsales ont été observées comme un symptôme très courant.

ZUSAMMENFASSUNG

Diese Langfristuntersuchung von nicht behandelten skoliotischen Patienten wurde ausgeführt um die Invalidität und möglicherweise erhöhte Sterblichkeit zu bewerten die man von unserem Wissen hinsichtlich der pulmonalen und kardialen Schwierigkeiten die sich bei einigen dieser Patienten entwickeln vermuten konnte. Von den 130 Patienten die in der Abteilung von 1927-1936 gesehen worden waren konnten 117 verfolgt werden. Von diesen waren 20 gestorben. In einer gleichen Gruppe der allgemeinen Bevölkerung ist die Zahl der erwarteten Todesfälle 10-16 der Patienten in diesem Materiale starben an kyphoskoliotischer Cardiopathie mit einem cor pulmonale. Hinsichtlich der Arbeitsfähigkeit findet man dass diese im Verhältnis zur allgemeinen Bevölkerung sehr herabgesetzt war.

Hinsichtlich der Ätiologie der lateralen Krümmung wurde gefunden dass die kongenitalen thorakalen und neurogenen Skoliosen eine schlechte

tere Prognose haben als die idiopathischen rachitogenen oder polyomyelitischen

Bei 39 von 97 Patienten wurden Ruckenschmerzen als ein gewöhnlich vorkommendes Symptom beobachtet

REFERENCES

- 1 Aepli L (1964) Das Ergebnis der Spondylotomie bei Skoliosen Jugendlichen im Hinblick auf die Lungenfunktion *Arch orthop Unfall Chir* 58 155-165
- 2 Bergofsky E H Turino G M & Fishman A P (1959) Cardiorespiratory failure in kyphoscoliosis *Medicine* 38 263-317
- 3 Blount W P Schmidt A C Keever E D & Leonard F T (1958) The Milwaukee brace in the operative treatment of scoliosis *J Bone Jt Surg* 40 A 511-523
- 4 Blount W P (1964) The Milwaukee brace in the treatment of the young child with scoliosis *Arch orthop Unfall Chir* 56 363-369
- 5 Chapman E W Dill B D & Graedel A (1939) The decrease in functional capacity of the lungs and heart resulting from deformities of the chest Pulmonary failure *Medicine* 18 167-202
- 6 Cook C D, Barrie H De Forest S A & Helliesen P J (1960) Pulmonary physiology in children III Lung volumes mechanics of respiration and respiratory muscle strength in scoliosis *Pediatrics* 25 766-774
- 7 Cotrel R (1962) Conservative management of scoliosis. in Proceedings of a symposium on Scoliosis Ed P A /rab National Fund for Research into Poliomyelitis and other Crippling Diseases Vincent House London p 18-20
- 8 Eriksson H & Foss Hauge M (1962) Cardiopulmonary function in scoliotic patients treated with spinal fusion *Acta orthop scand* 38 392-396
- 9 Fishman A I (1962) Pulmonary aspects of scoliosis in Proceedings of a symposium on Scoliosis Ed P A /rab National Fund for Research into Poliomyelitis and other Crippling Diseases Vincent House London p 52-53
- 10 Fishman A I (1962) Cardiac function in scoliosis in Proceedings of a symposium on Scoliosis Ed P A /rab National Fund for Research into Poliomyelitis and other Crippling Diseases Vincent House London p 9-81
- 11 Harrington F R (1963) The management of scoliosis by spine instrumentation An evaluation of more than 200 cases *South Med J* 56 1367-1377
- 12 Hodgson A R (1961) Correction of fixed spinal curves *J Bone Jt Surg* 47 A 1221
- 13 James J I P (1962) Classification and prognosis in Proceedings of a symposium on Scoliosis Ed P A /rab National Fund for Research into Poliomyelitis and other Crippling Diseases Vincent House London p 11-17
- 14 Mankin H J Crumham J J & Schack J (1964) Cardiopulmonary function in mild and moderate idiopathic scoliosis *J Bone Jt Surg* 46 A 53-62
- 15 Nilssonne U & Lundgren K D (1962) Longitudinal prognosis in idiopathic scoliosis *Nord Med* 77 1059
- 16 Pennington A & Friedmann B (1950) Prognosis in idiopathic Scoliosis. *J Bone Jt Surg* 32 A 351-395

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RÉSUMÉ

Cet examen à long terme chez des malades scoliotiques qui n'ont pas subi de traitement a été effectué pour juger de leur incapacité de travail et éventuellement du taux plus élevé de mortalité que l'on pouvait soupçonner en parlant des connaissances que nous avons des troubles pulmonaires et cardiaques qui se développent chez certains de ces malades. Il a été possible de retrouver la trace de 117 des 130 malades observés dans notre Département entre 1927 et 1936. 20 d'entre eux étaient décédés. Dans un groupe correspondant de la population générale le nombre des décès aurait vraisemblablement été de 10 à 16 des malades appartenant à ce matériel sont décédés de cardiopathie cyphoscoliotique avec cœur pulmonaire. En ce qui concerne la capacité de travail il a été constaté que celle-ci était fortement diminuée par comparaison avec la population générale.

Par rapport à l'étiologie de la courbure latérale on a constaté que les formes congénitales thoracogéniques et neurogéniques ont un pronostic plus favorable que les scolioses idiopathiques rachitogéniques et polio-myélitiques.

Chez 39 des 97 malades des douleurs dorsales ont été observées comme un symptôme très courant.

ZUSAMMENFASSUNG

Diese Langfristuntersuchung von nicht behandelten skoliotischen Patienten wurde ausgeführt um die Invalidität und möglicherweise erhöhte Sterblichkeit zu bewerten die man von unserem Wissen hinsichtlich der pulmonalen und kardinalen Schwierigkeiten die sich bei einigen dieser Patienten entwickeln vermuten konnte. Von den 130 Patienten die in der Abteilung von 1927-1936 gesehen worden waren konnten 117 verfolgt werden. Von diesen waren 20 gestorben. In einer gleichen Gruppe der allgemeinen Bevölkerung ist die Zahl der erwarteten Todesfälle 10-16 der Patienten in diesem Material starben an kyphoskoliotischer Cardiopathie mit einem cor pulmonale. Hinsichtlich der Arbeitsfähigkeit fand man dass diese im Verhältnis zur allgemeinen Bevölkerung sehr herabgesetzt war.

Hinsichtlich der Ätiologie der lateralen Kurve wurde gefunden dass die kongenitalen thorakogenen und neurogenen Skoliosen eine schlech-

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RUPTURE OF THE ROTATOR CUFF OF THE SHOULDER

Experiences of Surgical Treatment

By

HENRIK V A HEIKEL

Received 27 VIII 67

Undisturbed synchronous function of the glenohumeral acromioclavicular and sternoclavicular joints and of the so-called scapulothoracic and supraglenoid joints is indispensable for normal mobility in the shoulder joint. The supraglenoid joint is formed by the acromion and the coracoid process with the coracoacromial ligament on the one hand and the rotator cuff with the biceps tendon on the other with the subacromial bursa as joint capsule. The significance of this joint and of the smoothness of its surfaces should not be underestimated.

The muscles whose tendons together with the joint capsule form the rotator cuff strain the latter and it has been assumed that the main task of the supraspinatus muscle is to pull down and fix the humeral head against the glenoid cavity when at the initial stage of abduction the deltoid muscle tends to displace the humerus in direction of its longitudinal axis. When *Olsson* (9) observed that after rupture of the subscapularis tendon abduction was no longer possible he concluded that fixation is principally secured by the subscapularis and teres minor muscles. However *da Palma* (10) demonstrated that abduction was undisturbed even after extensive lesion of the rotator cuff. By selective blocking of the supraspinatus nerve *van Linge et al* (5) demonstrated that as long as the rotator cuff was intact failure of the supraspinatus function did not affect the extent but only the strength of abduction. They concluded that the only specific function of the supraspinatus muscle was to strain the rotator cuff and that in rupture of the cuff the functional disturbance was due to impaction of the injured tendon between the humerus and the acromion.

Rupture of the rotator cuff does not always give rise to disturbances

requiring treatment or even leading the victim to seek medical advice. Normal ageing is accompanied by degenerative processes which, in the rotator cuff first appear at a distance of about 1 cm from the greater tuberosity where the nutrition is poorest (*Rothman et al* (11)) and where the capsule is tightly stretched over the humeral head while the demand for a buffer effect against the acromion is greatest in abduction. Here both complete (full thickness) and incomplete ruptures of the rotator cuff occur and can be observed at autopsy in 20 to 30 per cent of all persons over 60 years old.

A sudden usually traumatic rupture however causes functional disturbances and pain. These symptoms occur immediately but may also not appear until a few days later possibly as a result of secondary traumatic bursitis (*Kernwein et al* (4)). The symptoms may subside spontaneously or after conservative treatment. However in considering *da Palma's* opinion that 90 per cent of all persons with rupture of the rotator cuff recover without surgical treatment it must be remembered that his series included both complete and incomplete ruptures and that the condition cannot always be diagnosed with certainty.

Since 1933 when *Codman & Oberholzer* performed the first arthrography of the shoulder joint the method has been developed and we have learned to diagnose total rupture of the rotator cuff arthrographically. Thus a basis has been obtained for prognosis and for assessment of the results of treatment and operative indications. However opinions are still divided as to the best method of treatment. While *Wachsmuth* (13) writes: "Reine Abrisse erfordern in fast jedem Falle eine operative Behandlung, da sonst eine erhebliche Funktionseinschränkung zurückbleibt" others recommend operative treatment only when good abduction is not restored by conservative treatment for 1 to 1½ months. *Da Palma* (10) 2 to 4 months *Campbell* (2) or 4 to 6 months *Debeyre et al* (3) *Adams* (1) does not advocate operative treatment of elderly patients as a rule and *Wagnusson* (6) is of the opinion that it is contraindicated in all inveterate cases and in recent cases when the patient is over 40 years old.

In view of these opinions I have felt it justifiable to report my experience of a series of 30 cases of rupture of the rotator cuff treated at the General Hospital Björneborg (Pori) during the period June 1959–June 1964. In 22 operatively verified cases there was complete rupture of at least 1 cm width while in 4 out of 8 conservatively treated cases arthrography indicated a small complete rupture and in 4 cases a probable diagnosis of incomplete rupture was made on the basis of

clinical examination (Thus the conservatively treated cases were estimated to be less severe than the operatively treated and the groups are not therefore comparable)

The series consists of 16 men and 14 women aged 40-67 years. The average age 56 years was the same for men and women and likewise for both conservatively and operatively treated patients. From the point of view of age the series is not so very satisfactory.

The injury occurred in 19 cases when the patient stumbled and fell once after a fall from a great height 7 times in traffic accidents once from a blow against the shoulder and once when lifting a weight. In one case pain and loss of power occurred without injury. When falling 14 patients had hit the shoulder against the ground and 4 had stopped their fall with the outstretched hand. The remainder could not remember such details. In 3 cases the humerus was dislocated.

Subjective and objective symptoms. The predominating subjective symptom was pain and reduced active mobility. The majority of the patients complained of pain in the area of the deltoid and radiating pain along the outer aspect of the upper arm.

Clinical examination revealed reduced abduction and flexion in about 4/5ths of the cases and in the remaining cases reduced strength of these movements (in two cases there was no mention of this however) (Figure 1).

Because of severe pain the corresponding passive movement was not measured in 13 cases. It was normal in 11 cases 120-160° in 4 and less than 90° in 2.

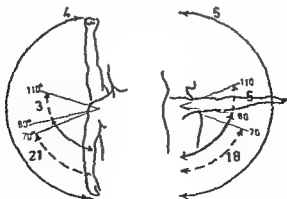


Figure 1 Schematic presentation of preoperative active abduction and flexion. The figures indicate no. of cases. Unbroken curved line indicates extent of mobility common to all cases in the respective group; a broken curved line indicating that in some cases the extent of mobility is as less than in the best cases of the group.

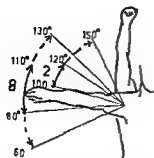


Figure 2 Schematic presentation of the one within which pain was felt during abduction and adduction

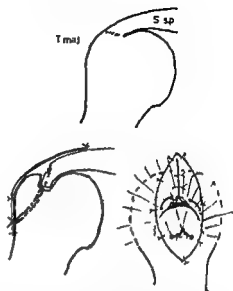


Figure 3 Schematic picture of the transition from the greater tuberosity to an intact rotator cuff of the unevenness that occurs when the rupture margin is anchored in a groove in the bone and of a residual defect of the rotator cuff and of the method according to which the defect and the unevenness were covered with a fascia graft

Seven patients with active abduction of less than 80° were able to maintain the arm in abduction of about 120–150° when it had been passively raised

In 10 patients pain at the rim of the acromion occurred or was aggravated on abduction or adduction within the sectors 60–130° or 100–150° (Figure 2). In 9 of these crepitation over the acromion was simultaneously heard

The effect of local anaesthesia was investigated in 7 cases only. In 6 of these cases active mobility improved in 3 cases from about 40° to normal abduction and flexion

Local tenderness to palpation over the greater tuberosity was a constant symptom. Pronounced tenderness on the ventral side of the joint in one case pointed to rupture of the subscapularis and this was verified at operation. Reduced strength of horizontal adduction gave reason to suspect such a rupture in another case. Arthrography confirmed the presence of rupture but since operation was not carried out the exact position of the rupture could not be established. A clear defect in the rotator cuff could only be palpated in one patient. There was no mention of muscular atrophy

Diagnosis Twelve patients were examined by an orthopaedist 0-7 days after the injury 7 patients within 8-30 days 6 within 1-3 months and 5 within 4-14 months. The diagnosis was made at the first clinical investigation in 23 cases and was subsequently verified by arthrography and at operation in 19 of these. In 3 cases in which the primary diagnosis was dislocation of the humerus and in 4 which after unsuccessful conservative treatment without an exact diagnosis were referred to an orthopaedist the diagnosis was made after treatment for some time and in all cases it was verified as above.

Treatment Operative treatment was suggested in all cases in which conservative treatment had been unsuccessful and primarily in all cases in which complete rupture had been demonstrated with certainty. However operation within 15 days after the injury could only be carried out in 5 cases in the remaining cases there was an interval of 1 to 18 months (Figure 4). Operation was refused or considered contra-indicated because of other diseases in 2 cases because of contracture in 1 marked muscular atrophy in 1 and insignificant clinical symptoms and arthrographic signs of a very small though complete rupture in 4 cases. All operations were carried out by the present writer.

As soon as rupture of the rotator cuff was suspected or demonstrated the arm was immobilized on an abduction splint until the pain had disappeared or until the patient was operated on. An abduction splint was used to enable active mobilization.

Operative method and findings Lexer's incision detaching the deltoid from the acromion was used in 19 cases and sabre-cut incision with osteotomy of the acromion according to Codman in 3 cases. The former incision is often accompanied by irritating haemorrhages from small arteries along the clavicle and the acromion and does not allow full exposure of a retracted supraspinatus tendon. Resection of the acromion as an additional measure was therefore necessary in 6 cases. The sabre cut incision allows a wider field of view and causes less bleeding but the osteotomy requires osteosynthesis which may interfere with the intended early isometric muscle training.

In 20 cases rupture of the supraspinatus tendon was observed. In 13 of these cases the rupture also involved part or all of the infraspinatus tendon and in 2 cases also a part of the teres minor tendon and in 2 cases part of the subscapularis tendon. Rupture of the subscapularis tendon alone occurred in 2 cases. A slit from the transverse rupture along the ventral side of the supraspinatus tendon was observed in 4 cases and along its dorsal rim in 4 cases. The proximal margin of the

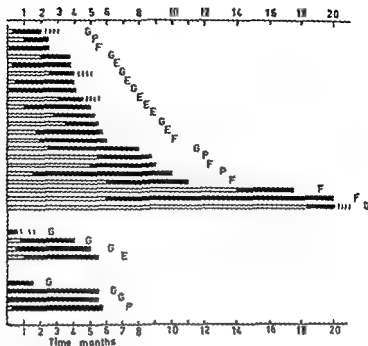


Figure 4 Diagram showing a) the interval between injury and operation and the beginning of mobilization treatment respectively (unfilled section of column) b) duration of sickleave from operation and the beginning of mobilization treatment respectively (filled section of column) c) total sick leave (whole column) and d) the result of treatment in each case (E excellent G good F fair P poor). The uppermost group of columns indicates operatively treated cases, the middle group conservatively treated and arthrographically verified cases and the lowest group clinically diagnosed and conservatively treated cases.

Rupture was more or less retracted. In one case in which intense physical therapy had been given for 3 months and in which the rupture comprised the entire rotator cuff with the exception of the crural part of the teres minor tendon retraction was so marked that despite resection of the acromion it was impossible to reach the proximal margin of the rupture and reconstruction could not be carried out. (However it might have been possible to carry out reconstruction according to the method published four years later by Debye *et al.*, i.e. mobilization and lateral displacement of the supraspinatus muscle).

In only one case did the rupture clearly comprise the area in which the blood supply is considered to be poorest while in the remaining cases the distal stump of the tendon was shorter. This might have been the result of wear through friction against the acromion. In two cases loose cicatricial tissue was observed between the margins of the rupture.

but it was so frail that it could hardly be expected to result in lasting healing. Kernwein *et al* (4) state that they have never seen signs of spontaneous healing. The biceps tendon which Samilson *et al* (12) often found at arthrography to be injured in connexion with rupture of the rotator cuff was completely torn in one and subluxated and partly torn in two cases.

Reconstructive measures. The margins of the rupture which were as a rule frayed and thickened were resected. The proximal rim was fixed with two to four mersilene sutures carried through burr holes in the bone along a groove about 1/2 cm deep chiselled cranially and when necessary dorsally of the greater tuberosity. The obliquely divided distal stump of the tendon was sutured with catgut over the proximal end in order to achieve as smooth a cuff surface as possible. Longitudinal ruptures were closed with chromic catgut. If retraction was too powerful to allow the entire proximal rupture margin to be fixed into the bone groove the remaining defect was closed as completely as possible with thin mersilene and chromic catgut. I became increasingly convinced of the importance of reconstructing as smooth a surface as possible and of avoiding projection of the greater tuberosity over the cuff surface. It was evident that a persistent opening between the joint capsule and the subacromial bursa would never heal spontaneously. Therefore in one case in which the defect could not be completely closed I covered both the opening and the suture line with a free fascia lata graft. The end result was good at any rate in this one case.

Postoperative treatment. After the operation the arm was immobilized on an abduction splint or in a thoracobrachial plaster cast. Active deltoid exercises were commenced after 3-6 weeks in 4 cases preceded by isometric contraction exercises for 2 weeks. As soon as the patient was able to lift his arm actively from the abduction splint (or the cast plaster cast) the splint was replaced by a wedge pillow and while active exercises were continued the abduction support was gradually reduced. (Owing to a misunderstanding on the part of the staff immobilization was interrupted twice without preceding active abduction exercises. Reoperation of one of these patients revealed that a new rupture had occurred proximally of the primary rupture and that this new rupture could no longer be closed.) Active exercises were continued for 1½ to 3 months or until enough mobility and strength had been achieved that further improvement would occur at home and at work. In one case this treatment was discontinued by the patient after 2 weeks.

Pain which rendered mobilization more difficult occurred in 4 cases

at the greater tuberosity and in 1 at the bicipital sulcus. In all but one case the pain disappeared after one or a few injections of Lidocain and hydrocortisone.

Conservative treatment alone consisted of active mobilization preceded in acute cases by immobilization for 2-4 weeks on an abduction splint. In one case with highly reduced passive mobility and arthrographically demonstrated completed rupture mobilization was carried out by force. In 8 cases satisfactory mobility and freedom from pain were achieved after mobilization treatment of 2-4½ weeks while in one case the treatment had to be continued for 2½ and in one for 4½ months.

The period of sick leave in the operatively treated group was 2-20 months (average 7.8) and in the conservatively treated group 1½-6 months (average 4.6). Counted from the day of operation or the beginning of conservative treatment the incapacity for work lasted 2-6 months (average 4.4) in the first and 1½-5½ months (average 4.5) in the second group. These figures do not include five housewives who partly resumed their housework during the period of immobilization.

The results of treatment were estimated on the bases of a follow up examination carried out by myself in March 1965 when the period of observation for the operatively treated patients was 13-67 months (average 35) and for the conservatively treated patients 11-32 months (average 24). At examination I considered the patients' own opinions as to whether they had become symptom free, better or worse after the treatment and elicited information on spontaneous pain and pain on movement, severity and localization, movements provoking pain, weakness, stiffness and the effect of the symptoms on the capacity for work and on sleep. This information has been collected in Table 1.

The objective examination comprised measurement of active and passive mobility, strength of movement, crepitation and zones of painful movement, tenderness on palpation and muscular atrophy (Table 2). The degree of active abduction in the frontal plane was measured as well as the maximal abduction achieved by free deviation from this plane. In the same way flexion was measured in the sagittal plane and with free deviation from it. Rotation movements were measured at three different positions, i.e. with the upper arm adducted to the body, abducted to 90° and flexed to 90°. The degree of reduction of mobility was estimated by comparison with the contralateral healthy side. A reduction of 0-15° of abduction and flexion and 0-10° of rotation was considered *normal or insignificant*, 20-45° and 15-30° respectively.

Table 1 Subjective improvement and signs in surgically and conservatively treated cases

		Surg	Cons
General impression	No complaints	6	1
	Improved	13	6
	No change or worse	3	1
Aching or pain on movement	None	6	2
	Only occasionally	11	4
	Continuously	12	1
	Continuously disturbing sleep	3	1
Localization of pain	At acromion or undetermined	4	2
	Ventral to the joint	13	11
	Along the brachium	11	4
Movement which provokes pain	Flexion	6	3
	Abduction	11	4
	Outward rotation	11	1
	Inward rotation	6	1
Stiffness		8	1
Weakness		7	1
Working capacity	(Almost) unchanged	14	7
	Has changed to lighter work	6	—
	Incapable of work	2	1

Pain provoked by movements was present in 10 surgically and 3 conservatively treated patients

Among these are 5 housewives and 2 old age pensioners

moderate and a higher reduction *considerable*. A total deviation of 0-15° from the frontal and sagittal planes respectively at maximal abduction or flexion was considered *normal* or *insignificant*, 30° was considered *moderate* and a higher degree *considerable*. The strength was measured by the weight which the patient standing with his back against the wall and with elbow joint extended was able to lift to 90° at abduction and flexion respectively and comparing the result with the strength of the healthy arm. The method is admittedly inexact and does not take into account the normal difference between the "good" hand and the "poorer" hand nor of the fact that the significance of the difference between for instance 3 and 1 kg on the one hand and 15 and 11 kg on the other is not the same but nevertheless it was con-

Table 2 Residual symptoms in surgically and conservatively treated cases
(For explanation see text)

Kind of treatment			Surgical	Conservative
Active flexion	Restriction	insignificant	13	6
		moderate	4	1
		considerable	5	1
	Deviation	insignificant	20	7
		moderate	2	1
Active abduction	Restriction	insignificant	9	6
		moderate	7	1
		considerable	6	1
	Deviation	insignificant	20	7
		moderate	11	1
Restriction of active inward rotation	In abduction	insignificant	10	3
		moderate	3	3
		considerable	9	9
	In flexion	insignificant	18	6
		moderate	2	1
		considerable	2	1
	In adduction	insignificant	22	8
		moderate	—	—
		considerable	—	—
Restriction of active outward rotation	In abduction	insignificant	12	4
		moderate	7	9
		considerable	3	9
	In flexion	insignificant	11	6
		moderate	6	2
		considerable	5	—
	In adduction	insignificant	11	4
		moderate	8	1
		considerable	3	3
Reduction of strength	In abduction	insignificant	10	3
		moderate	7	3
		considerable	5	2
	In flexion	insignificant	10	3
		moderate	7	3
		considerable	11	9
Painful zone by abduction adduction			11	—
Tenderness			11	—
Crepitation			3	1
Apparent muscular atrophy			3	—
Abnormal humeros apular rhythm			8	1

sidered adequate as a rough measure of the degree of reduction of strength

On the basis of subjective estimation and objective examination the results of treatment were estimated as follows

I Excellent No subjective complaints and capable of doing previous work No spontaneous pain only moderate pain if any on straining Extent and power of active abduction and flexion normal or insignificantly reduced Extent and power of rotation normal or insignificantly reduced or moderately to highly reduced in one direction only

II Good Subjectively improved and capable of former work Moderate pain on movement and after strain Active abduction and flexion normal or moderately reduced rotation only moderately reduced in all directions or considerably reduced in one direction

III Fair Subjectively improved incapable of previous work but capable of continuous easier work Moderate but persistent or frequent pain which occasionally disturbs sleep Either (1) moderate pain on all movements (2) active abduction and adduction highly reduced and one of the movements highly painful or its strength considerably reduced or (3) rotation highly reduced

IV Poor Subjectively unchanged or worse cannot work for his living Persistent pain which disturbs sleep the extent and strength of all movements reduced and painful

On the basis of these criteria the results of treatment were considered excellent or good in 13 of the cases treated operatively and in 7 treated conservatively and poor in 3 cases and 1 case respectively (Figure 4)

The four cases in which the result was poor will be briefly described and the probable reason for the failure stated

Case 1 60 year old woman operated one month after the injury When post operative mobilization was commenced the abduction splint was removed by mistake and a new rupture occurred (see above) *Technical error and new rupture*

Case 21 A 55 year old man who had been treated elsewhere for over a year Large rupture which could not be closed at operation Postoperative pain which Lidocaine hydrocortisone injections failed to alleviate Persistent pain pain on movement and stiffness Objectively moderate reduction of mobility painful zone and crepitation Arthrography showed persisting connexion between the joint capsule and the subacromial bursa *Technically unsatisfactory operative result*

Case 22 63 year-old man operated on 5 months after the injury Operative findings and primary operative result as in case III After 5 weeks immobilization in a thoracobrachial plaster cast the cast was removed by a colleague who had not been adequately informed without preceding deltoid training Subjectively stiffness and pain on strain objectively all movements reduced *Technically unsatisfactory operative result and likewise after treatment probably a new rupture*

Case 24 52 year old man The injury was diagnosed as an incomplete rupture within 10 days of the injury Arthrography was planned but not carried out Mobilization which was commenced after 4 weeks on an abduction splint gave good results but when the patient returned to work as a dock worker the aching pain on movement and weakness returned Operation was suggested but refused *Probably underestimation of the extent of the injury Operative treatment might have given a better result*

DISCUSSION

Rupture of the rotator cuff seems to be more common than is generally assumed Particularly the possibility of rupture in connexion with dislocation of the humerus should be borne in mind Samulson (12) states that ruptures with dislocation are as a rule smaller than those without The fact that the two largest ruptures in my series were observed in cases of dislocation may have been due to enlargement of a primarily moderate rupture during intense active mobilization as described by Campbell (2) The fact that the retraction of the proximal margin of the rupture was assessed as considerable in only 1 of the 4 cases which were operated on within 15 days of the injury in 3 of the 6 operated on within 16-60 days in 4 of the 7 operated on within 2-6 months and in all patients operated on later than 6 months after the injury supports this assumption

Earlier reports that an intact supraspinatus tendon is not an absolute condition for active abduction were verified by the fact that in two patients with full active mobility (with reduced strength) rupture of the supraspinatus and part of the infraspinatus tendon was observed It is a common observation that rupture of the rotator cuff does not cause contracture In one of my arthrographically verified cases the contracture may have been present before the rupture occurred

An incision allowing adequate exposure and the possibility to reach even a far retracted rupture margin is necessary Not even resection of the acromion close to the acromioclavicular joint or corresponding osteotomy is always sufficient Debeyre's method is probably the best in inveterate cases

It is of great importance that the rotator cuff should be reconstructed so that its surface becomes whole and smooth and so that the greater tuberosity does not protrude In order to promote healing of a remaining defect of the rotator cuff McLaughlin (7) recommends resection of the joint cartilage beneath the defect so that the cuff heals by attaching to the bone However in such cases there is no hope of regaining full

mobility. The good result which I achieved with a fascia lata graft encourages continued use of this method.

In order to reduce the risk of interference between the greater tuberosity and the acromion, McLaughlin recommends acromioplasty or division of the coracoacromial ligament. I have not been able to observe any effect on the end results in 3 cases of acromioplasty or 11 cases of resection of the acromion, except that the latter is cosmetically ungainly. I have no experience of division of the ligament.

For postoperative treatment, Campbell (2) recommends balanced suspension until the wound has healed and then mobilization beginning with pendular movements with the arm hanging down. Wachsman (13), Adams (1) and Debeyre (3) suggest an abduction splint or thoracobrachial plaster cast for a period of 6 to 8 weeks. Active abduction within the first 6 to 8 weeks is not as a rule recommended. In half my cases active abduction movements from the splint were started after as little as 3 to 4 weeks and in the remaining cases after 4 to 6 weeks. The distribution of good and poor results is identical in the two groups. It seems more important to ensure that the deltoid muscle is trained before the abduction splint is removed and that the degree of the abduction support is reduced gradually so that stretching of the rotator cuff can be avoided than to continue immobilization for a certain number of weeks.

If the above case in which reconstruction could not be carried out and the 2 in which a new rupture (probably) occurred are excluded, we find that when operation was performed within 15-60 days after the injury, only excellent and good results were obtained while when operation was performed 6 months or more after the injury the result was never excellent and was good in only one case.

Preoperative mobilization treatment for 0-8 weeks was not found to have any effect on the results of treatment but if treatment had been given for a longer period and the patient had tried to resume work before the operation, the results tend to be poorer. If there is marked muscular atrophy before operation, postoperative mobilization is delayed. The operation is technically easier to perform before the proximal margin of the rupture has retracted. The total length of sick leave is shortened if preoperative mobilization treatment of long duration is not given.

CONCLUSIONS

Direct comparison of the operatively and conservatively treated groups is impossible because of the difference in severity of the cases between

the two groups. My experience with the first group has convinced me however that when the diagnosis of complete rupture of the rotator cuff with markedly reduced mobility, reduced strength and pain on movement is certain, early operation is best. Conservative treatment is justified when symptoms are insignificant, when complete or almost complete active mobility is demonstrated after intra-articular anæsthesia or when for other reasons operation or prolonged immobilization is contraindicated. I do not consider an age of over 60 years a contraindication. Co-operation with a skilful and energetic physiotherapist is essential for good results.

SUMMARY

22 cases of complete rupture of the rotator cuff were treated operatively and 8 (4 with arthrographically demonstrable complete but small rupture and 4 with clinically diagnosed incomplete rupture) conservatively.

At operation I aimed at anchoring the cuff in a groove chiselled proximally to the greater tuberosity and at reconstructing as even and smooth a surface as possible. In one case a fascia lata graft was used for this purpose.

On the basis partly of the patient's subjective opinion and partly of objective clinical follow-up examination the results were estimated as excellent or good in 13 operatively and in 7 conservatively treated cases. Stress is laid on the importance of postoperative immobilization in abduction which is gradually reduced after the deltoid has been exercised.

Observations at operation and the end results argue for early operative treatment of all cases with marked symptoms and without contraindications. An age of over 60 years is not by itself a contraindication.

RESUME

22 cas de rupture complète du muscle rotateur de l'épaule ont été traités chirurgicalement et 8 (parmi lesquels l'arthrographie a décelé une rupture complète mais petite dans 4 et le diagnostic clinique une rupture incomplète dans les autres 4) soumis à un traitement conservateur.

À l'opération j'ai cherché à fixer le muscle dans un sillon ciselé proximement à la grosse tubérosité en reconstruisant une surface aussi lisse que possible. Dans un cas une greffe de fascia lata a été utilisée dans ce but.

Partiellement sur la base de l'opinion subjective des malades et partiellement sur celle de l'examen clinique complémentaire les résultats ont été jugés excellents et bons dans 13 des cas opérés et dans des cas soumis au traitement conservateur. Les inconvénients proviennent de la durée de l'immobilisation post opératoire en abduction mais ont été progressivement réduits au fur et à mesure que le deltoïde a été entraîné pour reprendre sa fonction.

Les observations faites au cours de l'opération et les résultats finaux parlent en faveur d'un traitement opératoire précoce de tous les cas présentant des symptômes marqués sans contre indication. L'âge de 60 ans ne constitue pas comme tel une contre-indication.

ZUSAMMENFASSUNG

22 Fälle von vollständiger Ruptur der Rotatormanschette wurden operativ und 8 (4 mit arthrographisch nachweisbaren vollständigen aber kleinen Rupturen und 4 mit klinisch diagnostizierten unvollständigen Rupturen) konservativ behandelt.

Bei der Operation zielte ich darauf hin die Manschette in einer proximal von dem Tuberculum majus ausgehenden Rinne zu verankern und bei der Rekonstruktion eine möglichst ebene und glatte Oberfläche zu erhalten. In einem Falle wurde ein Fascia lata Streifen zu diesem Zwecke verwendet.

Teilweise auf Grund der subjektiven Meinung des Patienten und teilweise auf Grund klinischer objektiver Nachuntersuchung wurden die Ergebnisse als ausgezeichnet oder gut in 13 operative und 7 konservativ behandelten Fällen angesehen. Gewicht wird auf die postoperative Ruhigstellung in Abduktion gelegt, die stufenweise nach der Aufübung des M. deltoideus vermindert wird.

Beobachtungen während der Operation und die Endergebnisse sprechen zu Gunsten einer frühzeitigen operativen Behandlung aller Fälle mit ausgesprochenen Symptomen und ohne Kontraindikationen. Ein Alter von über 60 Jahren ist an und für sich keine Kontraindikation.

REFERENCES

1. Adams J. C. (1964) *Outline of Orthopaedics*. V. Ed. E. & S. Livingstone Ltd. Edinburgh.
2. Campbell, R. E. 1963, cit. from "Campbell's Operative Orthopaedics" IV. E. B. Mosby Co. Saint Louis.

- 3 Debeyre J Patte D & Elmehrik, E (1965) Repair of Ruptures of the Rotator Cuff of the Shoulder *J Bone Jt Surg* 47 B 36
- 4 Kernwein G A & Roseberg B (1961) Aids in the Differential Diagnosis of the Painful Shoulder *Clin Orth* 20 11
- 5 van Linge B & Mulder J H (1963) Function of the Supraspinatus Muscle and its Relation to the Supraspinatus Syndrome *J Bone Jt Surg* 45 B 750
- 6 Magnuson R (1959) In *Nordisk Larobok i Orthopedi* Svenska Bokforlaget Bonniers Stockholm
- 7 McLaughlin H L (1947) Common Shoulder Injuries *Amer J Surg* 74 287
- 8 Olsson O (1953) Degenerative Changes of the Shoulder Joint and their Connection with Shoulder Pain A Morphological and Clinical Investigation with Special Attention to the Cuff and Biceps Tendon *Acta chir scand* Suppl. 181
- 9 Olsson O (1958) Rupture of the Tendon of the Subscapular Muscle Report of one Operated Case and Notes on the Mechanism of the Shoulder Joint. *Acta chir scand* 114 224
- 10 da Palma A F (1950) Surgery of the Shoulder J B Lippincott Co Philadelphia
- 11 Rothman R H & Warke W W (1965) The Vascular Anatomy of the Rotator Cuff *Clin Orth* 41 176
- 12 Samilson R L, Raphael R L, Post L, Noonan C, Siris E. & Raney F L, Jr (1961) Arthrography of the Shoulder Joint *Clin Orth* 20 21
- 13 Wachsmuth W (1956) In *Allgemeine und Spezielle Chirurgische Operationslehre* Aufl. II Springer Verlag Berlin

ADDENDUM

Since this article was written I have operated on 5 further cases of arthrographically verified rupture of the rotator cuff 1 a 67 year old man and 4 45-53 year old women

the injury through a short incision along the lateral border of the acromion. The arm was postoperatively immobilised primarily on a wedge pillow later in a thoracobrachial plaster. Owing to severe obscure pain the patient could not cooperate and a contracture developed. Despite intense physiotherapy the end result 2 years after the operation was "poor" (no pain but 50 per cent restriction of movement).

The other patients were operated by the method of Debeyre. In cases 32 and 33 operated on 1½ and 3 years after the injury respectively the supraspinatus muscle was advanced laterally and in case 32 the suture line in the cuff was covered with a fascia lata graft. At after examination of case 32 one year after the operation the result was excellent. In case 33 and in cases 34 and 35 in which the reconstruction was performed within one month of the injury the intermediate result, as judged 7 6 and 5 months after the operation were fair, excellent and good respectively.

I have found the approach described by Debeyre superior to the other incisions because it allows free exposure and lateral advancement of the retracted supraspinatus muscle without which reconstruction would have been impossible in my cases 32 and 33.

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BOECK'SCHE SARKOIDOSE (MORBUS SCHAUMANN) DER HANDMUSKULATUR

Von

GÖSTA FRYKMAN & LARS WÄRTENSON

Received 11 vi 67

Tuberkuloide Granulome wie sie beim Morbus Schaumann (Boeck'sches Sarkoid) bekannt sind aber eine andere Lokalisation als in Lymphknoten aufweisen haben verschiedene Autoren bereits früher beschrieben (Licharew 1908 Mucha und Mitarbeiter 1919 Sundelin 1920 Jungling 1928 Bergel und Mitarbeiter 1933 Harrell 1940 Gravesen 1942 Oppenheim und Mitarbeiter 1947 Snorrason 1947 Bates und Mitarbeiter 1948 Krabbe 1949 Myers und Mitarbeiter 1952 Powell 1953 Danbolt 1954 Devic und Mitarbeiter 1955 Maurice 1955 Warburg 1955 Ammit-boll 1956 Bunnell 1956 McConkey 1958 Kock 1959 Brain 1960 Boyd 1961 Adams und Mitarbeiter 1962)

Nicht ungewöhnlich sind derartige Veränderungen in den Lungen im Magen in der Leber der Milz dem Pankreas den Hoden der Parotis in den Tranendrüsen und in der Uvea. Sogar im Hirn und im Myokard sind typische Granulome angetroffen worden. In der Skelettmuskulatur kommen sie der Literatur entsprechend vorwiegend im Musculus gastrocnemius vor. Im Skelett sind die Granulome praktisch immer in den Phalangen der Finger und der Zehen gelegen.

Lokalisationen von tuberkuloiden Granulomen der Hand werden von Howard in Handbuch Bunnells als ungewöhnlich angegeben und treten nach dessen Angaben nur in Form von Hautinfiltration oder im Skelett der Phalangen auf. Weder Pacl (1939) noch Howard Bunnell (1956) beschreiben eine Lokalisation in der Handmuskulatur oder anderen Handweichteilen. Ähnliche Angaben konnten auch bei anderen Verfassern die über Handtumoren geschrieben haben (Mason 1937 Dübén 1960) nicht vorgefunden werden. Finzi, Compton und Mitarbeiter haben 1961 zwei Fälle von tuberkuloiden Granulomen der Thenar-muskulatur beschrieben.



Bild 1 Histologisches Präparat Boeck's Sarkoid in Handmuskulatur 30 \times vergrößert

Bild 2 Histologisches Präparat Boeck's Sarkoid in Handmuskulatur 80 \times vergrößert

Im Hinblick auf die seltenen Publikationen über in der Handmuskulatur lokalisierte Granulome der genannten Art hatten es die Verfasser für angezeigt einen Fall mit Tumor in den Handweichtheilen zu beschreiben bei welchem das rasche infiltrative Wachstum in einen der Interosseusmuskeln sowie der makroskopische Aspekt während der Operation den dringenden Verdacht auf Malignität erhelegte. Die pathologisch histologische Diagnose ergab überraschenderweise tuberkuloide Strukturen wie beim Morbus Schaumann (Boeck'sches Sarkoid).

Es handelte sich um einen 16-jährigen Knaben der wegen eines Tumors radial vom zweiten Metacarpophalangealgelenk der linken Hand zur Untersuchung kam. Der Patient beobachtete diese Veränderung seit 1 Monat, weil sie ziemlich rasch an Grösse zunahm und schmerzhaft waren. Der Tumor war immer von elastischer Konsistenz. Röntgenologisch zeigte das Handskelett keine pathologischen Veränderungen. Klinisch konnte man radial vom Köpfchen des zweiten Metacarpale der linken Hand einen haselnuss-grossen zweiteiligen

Tumor feststellen. Die Veränderung war in einem kleinen Bereich an der Haut fixiert, aber im übrigen gegenüber derselben frei beweglich. In der Tiefe konnte eine ausgesprochene Fixation am ersten dorsalen Interosseusmuskel vorgefunden werden. Der Tumor schien kaum unter dessen distalem Anteil zu liegen, war aber doch nicht scharf begrenzt. Präoperativ wurde über die Diagnosen Xanthom oder Ganglion diskutiert. Während der Operation konnte folgender Befund erhoben werden: Die Tumorbildung bezog in einem umschriebenen Bereich die Haut mit ein, wies aber zur Hauptsache eine Infiltration in den Musculus interosseus dorsalis I auf und war von bedeutend grosserer Ausdehnung als von aussen palpiert werden konnte. Der vom Tumor befallene Muskel wurde in ganzer Ausdehnung entfernt. Die exstirpierte Resistenz wies eine fleichige, weissbraune Schnittfläche auf. Makroskopisch liess man den Verdacht auf Malignität und dachte an die Myofibrosarkom-Pathologie. Pathologisch anatomisch fanden sich jedoch tuberkuloide Strukturen von der Art des *Vorbus Schaumann* (*Boeck'sches Sarkoid*). Es lagen keine Anzeichen für ein Neoplasma vor (*H. Hansson*).

Diese pathologisch anatomische Diagnose war eine Überraschung und veranlasste eine erneute eingehende Aufnahme der Anamnese. Hierbei ergab sich folgendes: Ein älterer Bruder des Patienten war im vorangegangenen Herbst in der Klinik für Lungenkranke unter der Diagnose *Sarkoid - Stadium I* behandelt worden. Unser Patient selbst hatte keinerlei Erkrankung der Luftwege durchgemacht. neuerdings ergab die Schirnbildungsuntersuchung der Lungen keinen pathologischen Befund. Die Blutsenkung war bei Spitaleintritt 3 mm.

Die durchgeführte Röntgenuntersuchung der Lungen ergab bilateral stark vergrösserte Hiluslymphknoten wie beim *Vorbus Schaumann* (*Boeck'sches Sarkoid*). Die Tuberkulinproben gewöhnlicher Verdünnung bis zu 1 mg waren negativ. Den pathologisch histologischen Befund der Hand entsprechend wurde die fortgesetzte periodische Kontrolle des Lungenbefundes angeordnet.

MİKROSKOPIE

Grossere und kleinere runde beziehungsweise unregelmässig handförmige Anhäufungen von Epitheloidzellen. Diese liegen stellenweise ganz dicht, sind stellenweise durch mehr oder wenig fibrilläre Mengen von sklerotischem Bindegewebe ersichtlich. Disseminierte Epitheloidzellenanhäufungen finden sich auch im Fettgewebe. Stellenweise sieht man Leberchen interstitiell in der quergestreiften Muskulatur. Manche von diesen eindeutig destruiert. Die meistens tuberkelzellähnlichen Epitheloidzellenanhäufungen enthalten nur an einzelnen Stellen ein vielkernige Riesenzelle teils

mit kantengestellten Kernen teils mit ungleichmässig verteilten Kernen. In angrenzenden Bindegewebsklerosierten Fettgewebe sieht man an einer vereinzelt Stelle Rundzelleninfiltrate

Nirgends werden käsige Nekrosen oder überhaupt Nekrosen gesehen

keine Fremdkörper Bilder

keine Zeichen auf Neoplasma

PAD Tuberkuloide Strukturen von einer Art wie sie bei dem Vorbus Schaumann gesehen werden

keine Zeichen auf Neoplasma

(H. Hansson)

DISCUSSION

Bei der Überprüfung der zugänglichen Literatur haben wir gefunden dass früher nur zwei Fälle von tuberkuloiden Granulomen in der Handmuskulatur (Crompton und Mitarbeiter 1961) beschrieben worden sind. Bei dem von uns hier beschriebenen Fall konnten derartige Veränderungen isoliert in der Handmuskulatur festgestellt werden. Sie erinnerten an ein Tumorgebilde. Das klinische und das peroperative Bild liessen Malignität vermuten. Es wurde der betroffene Handmuskel vollständig entfernt was den Wegfall einer für die Hand nicht unwichtigen Funktion mit sich führte.

Irgendwelcher Zweifel hinsichtlich der Diagnose des hier beschriebenen Falles durfte unter Berücksichtigung der übrigen klinischen Befunde kaum vorliegen.

Mit Rücksichtnahme auf die benigne Natur der Erkrankung durfte bei Auftreten von Handmuskulatur Veränderungen von Typus Schaumann (Boeck'sches Sarkoid) ein Eingriff geringeren Ausmasses als er im vorliegenden Falle ausgeführt wurde genügt haben. Bei sicherem Ausschluss einer Malignität muss aber doch empfohlen werden den ganzen Muskel zu entfernen weil – wie im vorliegenden Fall – der funktionelle Ausfall doch relativ leicht kompensiert werden kann. Man kann sich primär immerhin mit einer kleinen Probeexzision begnügen um zu der histologischen Diagnose zu gelangen und dadurch die aktuelle Muskelfunktion eventuell zu retten. Die während der Ausheilung auftretenden fibrosen Neubildungen sind im allgemeinen nach den einschlägigen Literaturangaben zu schliessen nicht so hochgradig dass dadurch eine bemerkenswerte Störung der Muskelfunktion befürchtet werden musste.

ZUSAMMENFASSUNG

Es wird ein Fall von tuberkuloiden Granulom ohne Nekrose vom Typus der *Schaumannschen Erkrankung* (*Boeck'sches Sarkoid*) beschrieben. Die Lokalisation betrifft die Handmuskulatur. Die Veränderungen legten den Verdacht auf einen Tumor nahe, dessen klinisches Bild und makroskopisches Aussehen an Malignität denken liess. Die pathologisch-anatomische Diagnose und das übrige klinische Verhalten trugen zur Sicherung der Diagnose bei.

RESUME

Description d'un cas de granulome tuberculoide sans necrose du type maladie de *Schaumann* (*sarcoide Boeck*). Par sa localisation il portait atteinte a la musculature de la main. Par le tableau clinique et son aspect macroscopique de malignite il laissait soupconner la presence d'une tumeur. Le diagnostic anatomo-pathologique et les autres faits cliniques sont portes a l'appui du diagnostic.

SUMMARY

A case of tuberculoid granuloma without necroses (of Schaumann's disease or Boeck's sarcoide) is described. The granuloma was for the main part localized to the *Musculus interosseus dorsalis I*. The clinical features and the macroscopical picture arouse suspicion of a malignant tumor. The patho-anatomical findings and the further clinical course disproved this suspicion.

LITERATUR

- 1 Adams R. D., Denny Brown H. & Pearson C. M. (1967) *Diseases of Muscle*. Ed. II. Harpers & Brothers, New York.
- 2 Ammitzbøll, F. (1956) *Acta rheum scand* 2: 3.
- 3 Bates G. S. & Walsh J. M. (1948) *Ann intern Med* 29: 306.
- 4 Bergel A. & Scharff O. (1933) *Wien klin Wochr* 46: 1794.
- 5 Boyd W. (1961) *A textbook of Pathology*. Lea & Febiger, Philadelphia.
- 6 Bruns R. (1960) *Proc roy Soc Med* 53: 821.
- 7 Bunnell S. (1956) *Surgery of the Hand*. Vol. 3. Lippincott, Philadelphia. (Tumors of the Hand by L. D. Howard Jr. M.D.)
- 8 Crompton M. R. & Mac Dermot V. (1961) *Brain* 84: 472.
- 9 Danholt A. (1954) *Medicinska framsteg*. Gleerup, Aschehoug & Schultz, Lund-Oslo, Copenhagen.
- 10 Devic M., Masson H. & Bonnefoy (1955) *Rev. neurol* 92: 563.
- 11 Duben W. (1960) *Chirurg* 31: 495.

- 12 Grayesen P B (1942) *Lymphogranulomatosis benigna* Akademisk handling Odense
- 13 Harrell G T (1940) *AM J Arch intern Med* 65 1003
- 14 Jungling O (1928) *Beitr Klin Chir* 143 401
- 15 Koek V G (1959) *Nord Med* 62 1036
- 16 Krabbe H H (1949) *Acta med scand* 136 Suppl 234 193
- 17 Licharew A (1908) *Derm Z* 11 253
- 18 Mason M L (1937) *Surg Gynec Obstet* 64 129
- 19 Maurice P A (1955) *Helv med Acta* 22 16
- 20 McConkey H (1958) *AM J Arch intern Med* 102 443
- 21 Mucha V & Orzechowski K (1919) *Wien Klin Wochr* 32 25
- 22 Myers G H, Cottlieb A W, Mattman P E, Eckley G W & Chason J L (1952) *Amer J Med* 12 161
- 23 Oppenheim A & Pollack R S (1947) *Amer J Roentgenol* 57 28
- 24 Pack G T (1939) *Tumors of the Hands and Feet* C V Mosby Co St Louis
- 25 Powell L W (1953) *Amer J clin Path* 23 881
- 26 Snorrason E (1947) *Nord Med* 36 2424
- 27 Sundelin P (1925) *Acta med scand* 62 442
- 28 Warburg M (1955) *J Neuropath* 14 313

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SLIPPED UPPER FEMORAL EPIPHYSIS

Clinical Study on Aetiology

By

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Received 13 VII 67

INTRODUCTION

The exact aetiology and pathogenesis of slipping of the upper femoral epiphysis have not yet been elucidated. Generally the cause is assumed to be hormonal imbalance during puberty combined with mechanical strain on the epiphyseal cartilage.

First an attempt will be made to sum up our present knowledge.

1 *Sex and Age*

Slipping of the upper femoral epiphysis occurs around puberty most often between 13-17 years of age in boys and between 11 and 13 in girls. Boys are more often affected. *Jerre* (1950) found 83 per cent boys among 168 patients; *Oram* (1952) 77 per cent among 147 and *Wilson et al* (1965) 71 per cent among 240.

2 *Endocrine Disorders*

The occurrence of dys-hormonal conditions in these patients may be explained in a very simplified way as follows. If the pituitary gonadotrophin production starts too late or is reduced the production of sex hormone will be delayed and a condition reminiscent of adiposogenital dystrophy (Frolich's syndrome) results. If the pituitary growth hormone production keeps high while that of the antagonistic sex hormones is normal pituitary gigantism may occur. Both conditions are transient.

Harris (1950) administered growth hormone to castrated male and female rats and compared the histological changes in the epiphyseal

cartilage with an untreated series and a series treated only with oestrogen. In the first mentioned group a widening of the layer of hypertrophied cartilage cells in the epiphyseal plate was noted. This layer represents a mechanically weak zone which the slip always affects. Thus an increased quantity of growth hormone will further weaken this zone.

Slipping of the upper femoral epiphysis may occur in obese boys with a feminine distribution of fat and the characteristics of hypogonadism—but rarely in the form of a pure Frolich type—in rapidly growing thin in some cases very tall patients and in normal boys (Key 1926 Shands 1957 Jackson Burrows 1957 Newman 1958). The reported frequency varies widely in the first type for instance from 20.4 per cent (Oram 1952) to 65 per cent (Howorth 1957). Howorth found the height or weight to be significantly above average in 60 per cent, half of whom were of the Frolich type. Jackson Burrows, comparing height and weight with the normal values, found endocrine defect to be probable in 42 per cent. In another 12 per cent he found a moderate overweight which was unusual and 4 per cent of the patients were unusually tall. Wilson *et al.* (1965) reported obesity in 70 per cent and a Frolich like appearance in 22 per cent. There are even transitions from the pure Frolich type to normality. Hypogonadism cannot be assessed accurately and the diagnosis is often based upon an estimate. Jackson Burrows reported that the menarche had occurred in only 2 of 38 girls before the slip was diagnosed.

Skeletal development, judging by X rays of the hands and wrists, was normal in 29 of Jackson Burrows' patients.

Hormone analyses on the 24 hour urine (17 ketosteroids, androgens, oestrogens and gonadotrophin) have not revealed abnormalities except in a few instances (Oram 1952 Jackson Burrows 1957). Pituitary disorders and hypothalamic tumours have been reported as solitary cases in large series of patients (Jerre 1950 Lofgren 1953) and as an isolated case (Bruns 1960).

Jackson Burrows characterized 30 per cent of the patients as normal.

3. Poisoning

Aminonitriles present in alfalfa in sweet peas (*Lathyrus odoratus*) may induce a typical histological appearance in animals (Ponsletti *et al.* 1954 Ponsletti 1957). The toxicity is greatly increased by simultaneous administration of growth hormone and reduced by hypophysectomy (Selye *et al.* 1957). Ferguson & Howorth (1931) diagnosed the majority

of their cases of slipped upper femoral epiphysis in July November viz 66 per cent *Andren & Borgstrom* (1959) diagnosed 54 per cent of their cases in June September They assumed that in the pastures the cows might ingest aminonitriles which were passed on to the patients through the milk

4 Mechanical Factors

Local mechanical factors must be decisive since slipping occurs in fact only in the upper femoral epiphysis while hormonal disturbances if any would be expected to affect all epiphyseal plates

a) *Side affected* Both hips are involved in 20-25 per cent (*Jerre* 1950 22.9 per cent of 166 pts *Oram* 1952 21.8 per cent of 147 *Wilson et al* 1965 25 per cent of 240 pts) but it is only in about half the cases that the slip occurs simultaneously on both sides *Unilateral* slipping affects the *left* hip significantly more often than the right viz in 73.4 per cent of 128 unilateral cases (*Jerre*) Correspondingly *Howorth* (1941) has reported 56 per cent of 113 *Oram* 65.5 per cent of 115 and *Wilson et al* 60 per cent of 180 cases *Jerre* found the left hip to be affected in 75 per cent of boys and in 64 per cent of girls *Oram* found the corresponding values to be 67 per cent and 58 per cent and *Jackson Burrows* 70 per cent and 50 per cent of 128 115 and 77 pts

b) *Trauma* Direct or indirect injuries are fairly uncommon in most cases mild and rarely of decisive importance *Oram* found single injuries in 27.8 per cent as a rule falls or kicks repeated injuries in 7.4 per cent but in 75 per cent of the patients the symptoms had started before the trauma occurred *Jackson Burrows* found relevant injuries prior to the onset of symptoms in 20 per cent simultaneously in 20 per cent and after in 12 per cent *Wilson et al* found injuries in 26 per cent

In slipping of the upper femoral epiphysis the femoral head gradually becomes displaced medially posteriorly and distally During walking the centre of gravity moves from side to side and this entails a shearing strain almost parallel to the epiphyseal plate This also happens when the leg is carried forward In games and physical exercises the left leg is the one which right handed persons use to take off

5 Familial Occurrence

The disease is rarely familial Among the siblings of the patients

Jerre found 2 per cent and *Oram* 3 per cent while *Hulson et al* found 5 per cent in the immediate family

PRESENT MATERIAL

An attempt was made to elucidate the aetiological problems by examining all young patients with slipped upper femoral epiphysis seen in the Orthopaedic Hospital Aarhus during the period 1957-1964 a total of 101 patients

1 Sex and Age

The material comprises 76 boys and 25 girls (25 per cent). The sex ratio and age distribution correspond exactly to those found by others (cf Figure 2)

2 Endocrine Disorders

(a) The height and weight were recorded in all cases when the slip was diagnosed and at later follow up visits until cessation of growth. Values for height and weight from the age of 7 were obtained from the school doctors' health cards in 95 cases (6 cards had been destroyed).

Table 1 gives the weight and height at the time of diagnosis of the slip. The weight is compared with the average weight for the height concerned in normals for each sex separately and the height is compared with the average height for the age concerned also for each sex separately (*Dossing* 1950). Both sexes show a marked tendency to obesity: 26 boys (34 per cent) and 7 girls (28 per cent) weighed at least 15 per cent more than the average. There was less variation in height. In 80 per cent of the boys and in 84 per cent of the girls it was within 0 ± 9 per cent and none above 14 per cent. i.e. slipping of the upper femoral epiphysis does not occur particularly in very tall patients. Figure 1 shows that very few were tall and thin. This figure illustrates the great variation in the weight with a tendency to obesity in both sexes.

To assess abnormalities of growth all the height and weight measurements from the age of 7 years are plotted on a special growth diagram (*Dossing* 1952). It applies to the 26 obese boys and 7 obese girls that they had been fat for many years (Table 2). Their obesity had been fairly constant; they had not gained in connection with their disease and the consequently restricted physical activity. The weight curve was normal for 30 boys and 7 girls with constant height/weight

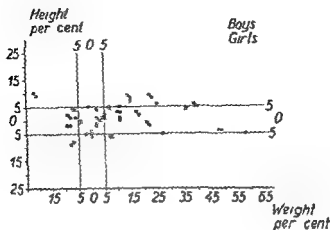


Figure 1 Height and weight of 101 patients when slipping of the upper femoral epiphysis was diagnosed in per cent of the average for normal children of the same age and sex

Table 1 Body weight in per cent of the average weight for the height concerned separately for each sex when slipping of the upper femoral epiphysis was diagnosed Height in per cent of the average height for the same age and sex (height measured at the same time as the weight) at the time of diagnosis

Per cent	Above average in %					±4 to -4	Below average in %		
	20-63	70-94	15-19	10-14	5-9		-(5-9)	-(10-14)	-(15-22)
Weight									
76 boys	16	4	6	11	6	27	7	1	3
23 girls	3	2	2	3	3	8	9		2
Height									
76 boys				6	15	44	9	1	1
23 girls				2	8	11	2		2

ratio and a normal weight from the age of 7 years until growth was completed 7 boys and 2 girls were slightly and constantly overweight (around 10 per cent) 2 boys and 3 girls slightly and constantly under weight. In 7 boys and 4 girls the curve altered from being normal to showing after the slip was diagnosed a gain of about 10 per cent and thereafter a further gain. A short lasting weight loss of about 5 kg continuing from a few months before until a few months after the slip had been diagnosed was observed in 15 boys and 4 girls (8 and 3 of the

Table 2 Obesity (at least 15 per cent in excess of the average weight) in 26 boys and 7 girls Duration (Broadly speaking unchanged height/weight ratio)

Obesity present prior to age (scale age in years)	4	5	6	7	8	9	10	11	12	13	14 years
26 boys			1	9	2	2	2	1	1	3	1
7 girls			1	1	2	1	1		1		
Duration of obesity so far at least (years)											
26 boys		1	6	5	3	2	3	1	2	3	
7 girls			2	1		1	2	1			

obese ones 2 and 1 of those showing about 10 per cent overweight and in 5 boys having an otherwise normal curve)

(b) *The adolescent growth spurt* The annual increment in height is normally increased in relation to the preceding years in boys from 12 to 15 and in girls from 10 to 13 but this adolescent growth spurt varies in degree and duration (Tanner 1962)

By plotting all the heights on graph paper the annual height increment was calculated and the adolescent growth spurt dated and compared with the age at which slipping of the upper femoral epiphysis was diagnosed. In 75 patients (59 boys and 16 girls or 78 per cent and 64 per cent) the condition was diagnosed during the first middle or last part of the growth spurt viz in 6, 15 and 38 boys and in 1, 6 and 9 girls. In 12 boys and 6 girls the growth spurt was indistinct and in 5 boys and 3 girls a few necessary measurements were lacking.

(c) *Skeletal development* In all 101 cases the skeletal age was determined on the basis of Greulich & Pyle's atlas (1950, 1959) in 60 pts at the time of diagnosis and in 41 6 months to 3 years after. In 2 growth had been completed. In 67 pts 2-5 examinations were performed before completion of growth at average intervals of 14 months. In 45 the result was the same every time in 20 one of the examinations differed by 1 standard deviation (S.D.) from the others and in only 2 pts did the skeletal age land in 3 groups each differing by 1 S.D. from each other. In 44 pts the maximum difference between the determinations was 0-6 months in 15 it was 7-12 and in 9 pts 13-33 months. As there was no tendency to normalization or increasing divergence but an even dispersion the mean value from several examinations was used as

Table 3 Skeletal age for 39 patients with slipping of the upper femoral epiphysis stated as (1) deviation from chronological age in standard deviations (2) average deviation from the chronological age in months and the variation within the individual groups (3) skeletal age for overweight patients and for patients who had the lowest weight and the greatest height

Standard deviation	-(4-13)	-(3-1)	-(2-3)	-(1-2)	0 \pm 1	+(1-2)
74 boys	6	5	12	26	30	1
20 girls	5	1	0	8	10	1
Percental distribution						
74 boys	17 = 23%			30%	40%	
20 girls	6 = 24%			32%	40%	
Average deviation (months)						
74 boys		4 ^o	29	18	-3	(14)
20 girls	58	24		1 ^o	-2	(10)
Range (months)						
74 boys		38-45	23-37	12-25	+6/-10	
20 girls	31-84			9-20	+3/-3	
Overweight ($\geq 15\%$)						
26 boys		1	0	6	13	1
7 girls	1			1	5	
Total 33 % distribution (boys-girls)		21%		21%	50%	
Tall thin						
12 boys			3	6	3	
8 girls	1			4	3	
Total 20		20%		50%	30%	

basis. According to *Greulich & Pyle* 1 S D for boys is 10-13 months and for girls 7-12 depending upon age.

Table 3 gives the skeletal age in S D divergence from the chronological age. Only 40 per cent of each sex showed less than 1 S D and only one of each sex + 1-2 S D. In all the other patients there was a delay of at least 1 S D. According to *Greulich & Pyle* 0 \pm S D should normally include 90 per cent of the pts. but in this material it included only 76 per cent. In 23 there was a delay of at least 2 S D. In Denmark where social conditions are favourable and medical prophylaxis extensive there is no basis for assuming that this might be due to nutritional

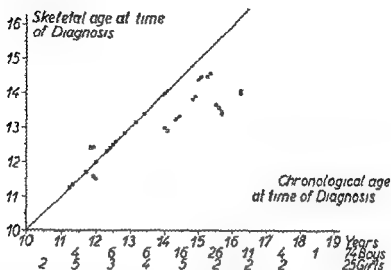


Figure 2 Chronological age of 99 patients when slipping of the upper femoral epiphysis was diagnosed and the skeletal age at that time. The delay in skeletal development is clearly apparent as the same age units and the same starting point are used on the abscissa and ordinate so that all the values would be on the oblique line if the skeletal age were normal.

causes or diseases. If anything there ought to be an influence in the positive direction.

Figure 2 gives the chronological age at diagnosis and the skeletal age at this juncture providing a constant divergence during the subsequent 3 years for the 39 pts. examined later. This has been confirmed by the repeated examinations. There is a marked dispersion of the chronological age (93 months) but far less (about 44 months) of skeletal age. Thus the slipping of the epiphysis must arise during an interval which from the point of view of skeletal development is narrow. At diagnosis the average skeletal age in boys was 13³ years (13 years 8 months) and in girls 12³ with a mean divergence of 10 and 16 months. In other words slipping of the upper femoral epiphysis was diagnosed 16 and 9 months before closure of the epiphyseal lines normally starts in the hand. (In the distal phalanges this closure starts in boys at 15⁰ years and in girls at 13⁰ years and continues rapidly in the remaining finger bones).

Figure 2 shows equally large age units on the abscissa and ordinate to illustrate clearly the delay in skeletal development. Up to the age of 13½ years in boys and 12 years in girls the values are distributed uniformly around the 45° line but thereafter all values for girls and

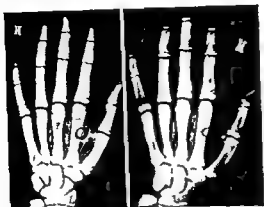


Figure 3 X rays of the hand and wrist of a boy aged 16½ years in whom the skeletal development is delayed by 3 years. At the age of 17½ years the skeletal development is still 2½ years delayed being now 15½ years (closure of the epiphyseal plates in most distal phalanges). Slipping of the upper femoral epiphysis was diagnosed at the age of 16½ years (Case 67)



Figure 4 X rays of the hand and wrist of a boy at the ages of 17½, 18½ and 19½ years. The delay in skeletal development amounts to 3½, 3½ and 3½ years respectively. Slipping of the upper femoral epiphysis was diagnosed at 17½ years of age (Case 8)

all but 5 for boys are below. The typical abnormality consists in failure of the epiphyseal plates to close. This can be easily and definitely assessed radiographically (Figures 3 and 4). As is apparent from Table 3 the deviation from the chronological age is of no slight order of magnitude.

Investigations of the skeletal age in 103 adolescent patients with Scheuermann's juvenile kyphosis from the same district had revealed no significant divergence from the normal values (Sørensen 1964).

The time of epiphyseal closure was controlled by comparing it with Hansman's findings (1962). A comparison could be performed in 50

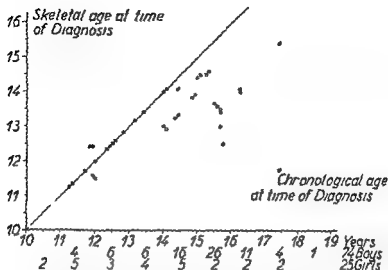


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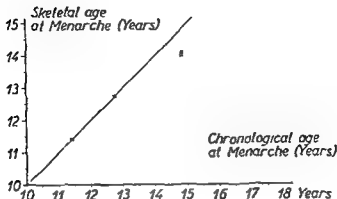


Figure 2 Age at menarche for 19 girls and skeletal age at the same juncture
Same age units as used in Figure 2

boys the androgen fraction was low averaging 18 per cent of the total value as compared with 28 per cent in the other 9. The skeletal age in 15 of the 17 boys was delayed by at least 1 S D average 24 months. Of these 17 boys 8 were obese and 3 were thin. In 7 pts under 15 years of age the total 17 KS were presumably low but for this age no normal values have been reported. Hypogonadism may have been present in these 17 boys and possibly in others too. Correspondingly 5 girls over 15 years of age had low total 17 KS including 2 with a low androgen fraction. One was obese. The skeletal age was delayed by an average of 42 months and in all cases by at least 1 S D.

The 24 hour output of *dehydroisoandrosterone* which is a pure adrenal metabolite was found to be constant in both sexes and normal from the age of 12 to 18 years.

The amount of androgen in the 24 hour urine in the 12-17 year group was found to be elevated for all age groups in both sexes and androgen was demonstrated 2 years before the normal time in the girls. The mean values were elevated from 1.5 per cent up to 3 times the value normal for the age and also in a somewhat jumpy way with increasing age. If the assessment is based upon skeletal age the values are even more elevated. By this analytical method at least 90 per cent of the urinary androgen activity ought to be demonstrated. An increased influence of androgen upon the epiphyseal plates ought to tend to earlier closure but we found the reverse. In recent years however it has become a well known clinical experience that determination of the 17 KS excretion and fractionation is a poor and insufficient parameter

of androgen status (Lindholm 1967). New improved analytical methods have been developed. As the named investigations are from 1957-1964 nothing definite can be concluded from the analyses.

(f) *Special abnormalities (case reports)* (1) A girl with slipping of the right upper femoral epiphysis aged 17½ years. Skeletal age —7½ years. At the age of 20 she was found to have calcific deposits around the sella turcica which was quite small. No gonadotrophin in the 24 hour urine, very low oestrogen values, genitalia hypoplastic but ovaries seen in an appendicectomy. At the age of 24½ years her skeletal age was —11½ years, no menarche. Diagnosis: Primary hypoplasia of the pituitary gland.

(2) A girl with slipped right upper femoral epiphysis, age 17½ years, skeletal age —5 years. At 21 years of age the sella turcica was found to be normal, the 17-hS were low (1.6 mg/24 hours), no oestrogens or gonadotrophin, genitalia very hypoplastic, no menarche, skeletal age —10½ years, sex chromatin female, BMR +20 per cent. Diagnosis: ?Absence of ovaries.

(3) A girl with slipped left upper femoral epiphysis, age 16½ years, skeletal age —3½ years, height/weight 135 cm/43 kg (—17/+40 per cent). At 17½ years, low 17 hS (3.7 mg/24 hours), no oestrogen demonstrated, gonadotrophin normal. At 19½ years the menarche had not yet occurred, skeletal age —5½ years, height/weight 139/50. Diagnosis: Dwarfism (primary?).

(4) A boy with slipped upper femoral epiphyses on both sides, age 16½ years, skeletal age —2½ years, height/weight 139 cm/44 kg (—19 per cent/—38 per cent), hypogonital, reduced gonadotrophin (below 3 mouse units/24 hours), very low 17 hS (1.3 mg/24 hours) and no increase following administration of metopirone. BMR —16 per cent. At 18½ years, skeletal age —3½ years, height/weight increased to 149/57 after treatment with gonadotrophin, thyroid and cortisone. Diagnosis: Pituitary dwarfism.

Thyroid diseases were not present among the patients. The paternal aunts of 3 boys and of 11 girls had been operated upon for goitre, probably toxic.

Diabetes mellitus was present in the mother of one girl. Otherwise there were no cases of diabetes in the families (pts. siblings or parents).

3 Poisoning

The symptoms had been present for an average of 5 months for an equal length of time in both sexes when slipping of the femoral epiphysis was diagnosed ranging from 1 day to more than a year. Table 4 lists the time of the year at which the symptoms started in 61 pts. with a history shorter than 6 months in whom this juncture could be established with most accuracy. Moreover it gives the time at which the diagnosis was made. The symptoms set in in June-September in 36 per cent of the boys and in 59 per cent of the girls (43 per cent of the total series). During the same period the diagnosis was made in 33 per cent of the boys and 48 per cent of the girls (37 per cent of the total series). The month of birth was June-September for 33 per cent of the patients and might just as well be used as a basis when considering how narrow is the skeletal age interval in which the disease starts.

Table 4 I Time of year at which the symptoms of slipped upper femoral epiphysis started (Length of history 0-70 weeks) II Time of year at which the diagnosis was made III Birth month

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I												
44 boys	3	2	1	4	2	1	7	2	11	2	6	8
17 girls	1	1		1	1	3	1	4	2	2	1	
II												
46 boys	7	9	5	8	5	7	1	11	11	5	6	6
20 girls	2	2	1	1	2		1	5	6	3	2	
III												
44 boys	10	8	4	9	8	12	5	7	2	2	4	5
17 girls	2	1	3		3		3	1	3	4	1	3

The period July-November does not show any major accumulation. The diagnosis was made in 38 per cent of the boys and 68 per cent of the girls. 26 per cent and 48 per cent were born during these months.

During the months July-December the symptoms had started in 70 per cent of the boys and 59 per cent of the girls having a history shorter than 6 months (total series 63 per cent boys and 50 per cent girls). In 46 per cent of the boys and 68 per cent of the girls the diagnosis was made and 33 per cent and 60 per cent were born during these months.

firmed the reported findings in respect to the age and sex distribution the disease occurring around puberty and the ratio boys/girls being 75 per cent/25 per cent. Bilateral involvement was found in 20 per cent and a left sided preponderance in the unilateral cases among boys (66 per cent) but not among girls. Familial occurrence is rare (3 per cent). 25 per cent had a history of initial trauma but usually too mild to have caused the slip.

There is a very marked variation in body weight with a pronounced tendency to obesity but with an even transition from normal weight to marked overweight and with an even distribution whereas height was normal with but little dispersion. Height and weight measurements from the age of 7 years until the cessation of growth showed for all the patients and in particular for the overweight ones that broadly speaking the height/weight ratio remained constant. It is demonstrated that the slipping of the epiphysis occurs during the adolescent growth spurt.

Determination of skeletal age on the entire material in most cases reportedly revealed a significant delay in skeletal development alike in both sexes the closure of the epiphyseal plates being delayed. Slipping of the upper femoral epiphysis occurs during a narrow skeletal age interval and in girls almost exclusively prior to the menarche. The correlation between the menarche and skeletal development is confirmed.

Hormone analyses including fractionated 17 ketosteroid determination on 24 hour urines gave no aetiological or pathogenetic information.

The tendency to obesity and delay of epiphyseal closure entails an increased stress on the epiphyseal plate at the upper end of the femur at the very age during which the young people are keen on games and at which there is a considerable gain in body weight.

RESUME

Après un court compte rendu de la littérature sur les connaissances que nous avons actuellement de l'étiologie et de la pathogenèse de l'épiphysiose de la tête femorale il est analysé un matériel de 101 jeunes malades. La littérature confirme la répartition selon l'âge et le sexe. On constate en effet que l'épiphysiose de la tête femorale se manifeste à l'âge de la puberté dans 75 pour cent des cas chez les garçons et dans 25 pour cent chez les filles. Elle est bilatérale dans 20 pour cent

des cas avec dans les cas unilatéraux une prépondérance pour le côté gauche chez les garçons (66 pour cent) mais non chez les filles. Il est rare que maladie ait un caractère familial (3 pour cent). Chez un quart des malades on trouve un trauma initial mais souvent si léger qu'il ne peut pas être à l'origine de la maladie.

On constate une très grande dispersion du poids avec une tendance marquée à l'adiposité avec transition régulière du poids normal au poids très élevé et une répartition égale des masses grasses tandis que la hauteur de la taille est généralement normale. Le contrôle de la hauteur de la taille et du poids à partir de l'âge de 7 ans et jusqu'à la fin de la croissance montre bien pour tous les malades et en particulier pour ceux qui ont un poids trop élevé que le rapport entre la hauteur et le poids est dans l'ensemble resté constant. Il est démontré que l'épiphysiose apparaît dans la dernière phase de la croissance de l'adolescent.

La détermination de l'âge des os effectuée chez tous les sujets pour la plupart à plusieurs reprises montre qu'il y a un retard marqué dans le développement des os qui est le même pour les deux sexes la fermeture des plaques épiphysaires étant retardée. En ce qui concerne l'âge des os la maladie se manifeste dans un intervalle de temps limité et chez les filles pour ainsi dire exclusivement avant la première menstruation. Un rapport entre la menstruation et le développement des os est confirmé. Des analyses d'hormones avec la détermination au 17 kélostéroïde fractionné de l'urine de 24 heures n'a pas donné de nouveaux renseignements susceptibles d'élucider l'étiologie et la pathogenèse.

La tendance à l'adiposité et le retardement de la fermeture épiphysaire entraînent une pression accrue sur la plaque épiphysaire de l'extrémité fémorale supérieure justement à l'âge où il est courant de pratiquer du sport et où le poids du corps augmente considérablement.

ZUSAMMENFASSUNG

Nach einer kurzen Literaturübersicht über unser gegenwärtiges Wissen der Ätiologie und Pathogenese der Epiphysiose capitis femoris (ecf) wird ein Material von 101 jungen Patienten (ppt) analysiert und die Literaturangaben hinsichtlich des Alters und der Geschlechterverteilung werden bestätigt indem ecf um die Pubertät in 75 Prozent der Fälle bei Knaben und in 25 Prozent bei Mädchen auftrat. Ecf tritt beiderseits in 25 Prozent mit linksseitigem Übergewicht in den seitigen Fällen bei Knaben auf (66 Prozent) aber nicht bei Mä-

Familiäres Auftreten ist selten (3 Prozent) Bei $\frac{1}{4}$ findet man Traumata die jedoch oft so leicht sind dass sie nicht als Ursache angesehen werden können

Man weist eine sehr starke Gewichtszunahme mit ausgesprochener Neigung zur Adipositas aber mit gleichmässigem Übergang von normalen Gewicht zu schwerem Übergewicht und mit gleichmässiger Verteilung nach wiegen die Grosse normal, mit nur geringer Zunahme verbleibt Grosse und Gewichtsmessungen vom 7 Jahrs Alter bis zum Wachstumsabschluss zeigen für alle gut und besonders für die Überwichtigen dass das Grosse Gewichtsverhältnis im grossen ganzen konstant war Man weist nach dass die es sich während des beschleunigten adolescenten Wachstums entwickelt

Knochenalterbestimmungen im ganzen Materiale bei den meisten mehrfach ausgeführt, haben gezeigt dass eine bezeichnende Verzögerung der Knochenentwicklung besteht gleich bei beiden Geschlechtern indem die Schliessung der Epiphysenscheiben verspätet ist Es tritt in einem knochenaltermässig knappen Zeitraum auf und bei Mädchen beinahe ausschliesslich vor der Menarche Die Beziehung zwischen der Menarche und der Knochenentwicklung wird bekräftigt

Hormonbestimmungen mit fraktionierter 17 ketosteroidbestimmung des Tagurins haben keine neuen Aufklärungen gegeben die zur Klärung der Ätiologie und Pathogenese beitragen könnten

Die Neigung zur Fettleibigkeit und die Verspätung Epiphysenschlusses führten zur vermehrten Belastung der Epiphysenscheibe am obersten Femurende gerade in einem Alter wo Sportausübung sehr ausgedehnt ist und in dem das Körpergewicht bedeutend zunimmt

REFERENCES

- Andren L. & Borgstrom A. E. (1959) Seasonal Variation of Epiphysiolysis of the Hip and Possibility of Causal Factor *Acta orthop scand* 28 27-76
- Bojlen A. W. Rasch G. & Weiss Bentzen M. (1954) The Age Incidence of the Menarche in Copenhagen *Acta obstet Gynec scand* 33 405-433
- Bruns, D. (1960) Hüftkopfeiphysenlösung bei einer 22jährigen Manne mit hormonell gestörtem Wachstum *Z orthop* 92 453-57
- Dassing J. (1950) Gennemsnitsværdier for vægt-højde-alder forhold hos drenge og piger i skolealderen *Ugeskr Læger* 112 1171-1181
- Dassing J. (1952) Determination of Individual Normal Weights of School Children Thesis Munksgaard Copenhagen (See *Ugeskr Læger* 114 1977-1984)
- Ferguson A. & Howorth M. B. (1931) Slipping of the Upper Femoral Epiphysis *J.A.M.A* 97 1867-1870
- Greulich W. W. & Pyle S. I. (1950 1959) Radiographic Atlas of Skeletal Development of the Hand and Wrist Stanford Calif Stanford University Press

- Harris W R. (1950) The Endocrine Basis for Slipping of the Upper Femoral Epiphysis *J Bone Jt Surg* 32 B 5-11
- Hansman C F (1962) Appearance and Fusion of Ossification Centers in the Human Skeleton *Am J Roentgen* 88 476-487
- Howorth M B (1941) Slipping of the Upper Femoral Epiphysis *Surg Gynec & Obstet* 73 723-729
- Howorth M B (1957) Slipping of the Upper Femoral Epiphysis. *Clin Orthop* 10 148-173
- Jackson Burrows H (1957) Slipped Upper Femoral Epiphysis *J Bone Jt Surg* 39 B 644-658
- Jerre T (1950) A Study in Slipped Upper Femoral Epiphysis *Acta orthop scand Suppl* No 6
- Johnsen S W (1956) Fractionation of Urinary 17 ketosteroids *Acta endocrinol* 21 127-145
- Key J (1956) Epiphyseal Coxa Vara of Displacement of the Capital Epiphysis of the Femur in Adolescence *J Bone Jt Surg* 8 53
- Lindholm J (1967) Androgen—speciellt Testosteron *Læstlr Læger* 129 1482-1486
- Lofgren L (1953) Slipping of Upper Femoral Epiphysis Signs of Endocrine Disturbance Size of Sella Turcica and 2 Illustrative Cases of Simultaneous Slipping of Upper Femoral Epiphysis and Tumor of the Hypophysis *Acta chir scand* 106 153-165
- Newman H H. (1958) Slipping of the Upper Femoral Epiphysis *Lancet* II 499-501
- Oram V (1959) Epiphysiolysis Capitis Femoris Thesis Universitetsforlaget Aarhus
- Ponsetti V & Shepard S (1954) Lesions of the Skeleton and other Mesodermal Tissues in Rats Fed Sweet pea (*Lathyrus Odoratus*) Seeds *J Bone Jt Surg* 36 A 1031-1058
- Ponsetti V (1957) Skeletal Lesions Produced by Ammoniteils *Clin Orthop* 9 131-144
- Selye H & Bois P (1957) Effect of STH on Experimental Lathyrism *Proc Soc Exp Biol Med* 94 133-137
- Selye H & Ventura J (1957) Effect of Hypophysectomy and Substitution Therapy with Sth upon Experimental Bone Lathyrism. *Amer J Path* 33 219-273
- Shands A R (1975) Handbook of Orthopaedic Surgery 5 ed. The C. V Mosby Co St. Louis
- Simmonds A. & Grenlich W W (1943) Menarchal Age and the Height, Weight and Skeletal Age of Girls Aged 7 to 17 Years *J Ped at* 22 518-548
- Sørensen K H (1964) Schruernmann's Juvenile Kyphosis. Thesis. Munksgaard, Copenhagen
- Tanner J M (1967) Growth at Adolescence Blackwell Oxford
- Wilson P D Jacobs B & Schechter L. (1965) Slipped Capital Femoral Epiphysis *J Bone Jt Surg* 47 A 1198 1245

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OPERATIVE TREATMENT OF OSTEOARTHRITIS OF THE DYSPLASTIC HIP JOINT

By

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Received 27 II 67

McMurray (1935) advocated his oblique intertrochanteric osteotomy with medial displacement of the distal fragment for osteoarthritis of the hip. In 1950 *Pauwels* introduced varus osteotomy without displacement an operation which has been used chiefly on young adults with painful dysplastic hips. His procedure is based on the principle of an increase in weight transmitting areas of the articular surfaces. With his method he demonstrated that osteoarthritic hip joints have a remarkable regenerative power regardless of the stage of the disease or the age of the patient. Loss temporary hanging hip operation has also secured a place in the treatment of degenerative hip disease. It was proved that his operation also relieves pain and promotes regeneration of the affected joint. It is frequently used in patients too old to tolerate such major operations as arthrodesis and osteotomy. Furthermore in cases with medial osteophyte formation *Pauwels* tried varus osteotomy combined with release of the muscles about the hip to increase the weight transmitting areas of the articular surfaces. In addition he theoretically demonstrated the following three factors which improve the degenerative changes in the joint:

- 1 Reduction of intermittent pressure in the hip during walking
- 2 Reduction of pressure caused by muscle tension
- 3 Increase in the size of the areas of the joint surfaces on which these forces act

Furthermore *Pauwels* demonstrated the mechanism of osteotomies which he compared with a release operation in overcoming vicious muscle pull at the hip (Figures 1 and 2). In his opinion the varus

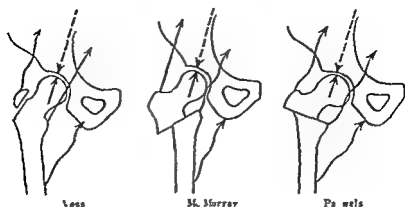


Figure 1 Drawings adopted from Pauwels illustrate the muscles that are relaxed to relieve pressure on the hip by the Voss' original hanging hip operation by the McMurray's osteotomy and by the Pauwels varus osteotomy

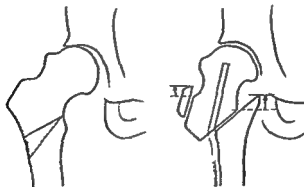


Figure 2. Pauwells valgus osteotomy accompanied by the muscle release operation

osteotomy meets three demands for improvement of the disease and valgus osteotomy combined with release operation meets two demands. McMurray's displacement osteotomy also reduces the load acting on the joint like Voss hanging hip procedure.

An incongruity between the articular surfaces is one important etiological factor of osteoarthritis of the hip. It may be due to dysplasia of the femoral head or acetabulum or both with or without coexisting subluxation of the joint. It may be acquired for instance as a result of a trauma and it may also be traumatic. Another group is made up of cases of coarthritis whose pathogenesis is not yet perfectly



Figure 3 Roentgenogram showing resection of the outer edge of the acetabulum in a dog

understood. Follow up studies of the clinical process in a large series of osteoarthritis of the hip suggest that in Japan the vast majority of cases is caused by acetabular dysplasia. We therefore undertook an experimental study of the biomechanism responsible for the development of osteoarthritis of the hip in dogs in which the superior outer edge of the acetabulum was resected. On the basis of the results of clinical studies reported by many authors mentioned above and observations made in our clinical and experimental studies we were able to lay down basic principles of treatment of osteoarthritis of the hip with incongruity. Furthermore on the basis of these principles various operative procedures were performed in 50 cases of osteoarthritis of the hip. The results of our studies are reported below.



Figure 4 Pathological changes in the femoral head in a dog four months after resection of the outer edge of the acetabulum. The mushroom shaped femoral head is seen in the gross specimen (A), roentgenogram (B) and histological section (C). The histological picture (C) shows slight abrasion of the central part of the articular cartilage and replacement of the red marrow with fatty tissue accompanied by formation of osteophyte around the head.



Figure 5 Pathological changes in the femoral head in a dog five months after resection of the outer edge of the acetabulum. A mushroom shaped femoral head is seen in the gross specimen (A) roentgenogram (B) and histological section (C). The histological picture shows almost complete loss of the articular cartilage, destruction of the bony trabeculae at the top of the head accompanied by thickening of the remaining trabeculae and formation of a large osteophyte around the head (C). In the lateral non pressure part of the head there is a region with thin trabeculae seen as a localized radio translucent area in the roentgenogram (B).

Experimental and Clinical Studies on the Development of Osteoarthritis in the Hip with a Defect of the Outer Superior Acetabular Roof

When the outer superior edge of the acetabulum was resected in adult dogs (Figure 3) degenerative arthritic changes developed within five to six months after operation. The results of this experiment are summarized as follows:

- 1 Abrasion of the central localized part of the articular surfaces due to abnormal friction was the first pathological change which appeared in the course of the experiment (Figures 4 A, 5 A and 6 A).
- 2 With time osteophytes formed around the femoral head which then migrated from the center of the acetabulum (Figures 4 and 5).
- 3 On histological examination of the femoral head within one to two months after operation almost all the animals showed destruction or loss of the central small localized articular surface and thinning or loss of the trabeculae in the upper part accompanied by replacement of red marrow with fatty tissue (Figure 4 C). These pathological changes were followed by reactive proliferation of the cartilage cells in the articular cartilage and reactive thickening of the remaining trabeculae and new bone formation around the head (Figure 5 C). In typical cases five to six months after operation marked thinning of the trabeculae or the formation of cysts was found in the lateral part



Figure 6 Pathological changes in the femoral head in a dog six months after resection of the outer edge of the acetabulum. Formation of a large cyst is found in the lateral part of the femoral head which is subject to least pressure.

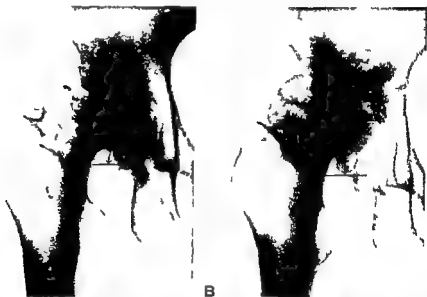


Figure 7 Roentgenograms showing rapid upward migration of the femoral head in the dysplastic hip with osteoarthritis. Figure 7 A in November 1964. Figure 7 B May 1965. The upward migration of the femoral head was accompanied by an enlargement of the medial osteophyte indicated by arrows.

of the head which was subjected to least pressure (Figures 5 C and 6 C). Similar pathological findings are also often made in human osteoarthritis of the hip. Two roentgenograms made at an interval of six months in a case of osteoarthritis of the hip with acetabular dysplasia are reproduced in Figures 7 A and B. Figure 7 A shows acetabular



Figure 8 Dysplastic hip with degenerative arthritis. Several cysts are arranged in the oblique equatorial plane of the femoral head where shearing stress is supposed to act.

dysplasia, narrowing of the cartilage space and slight upward migration of the femoral head with formation of lateral cysts and a small medial osteophyte. The roentgenogram (Figure 7 B) made six months later revealed rapid progress of upward migration of the femoral head followed by enlargement of the medial osteophyte. Figure 8 shows a moderately advanced case of osteoarthritis of the right hip. In this figure the mushroom-shaped femoral head contains several cysts arranged in the oblique equatorial plane. These findings suggest that a shearing stress, as indicated by arrows, continuously acts on the medial longitudinal weight-bearing trabeculae in the femoral head, resulting in their gradual destruction followed by reactive formation of osteophytes around the femoral head and upward migration of the femoral head. In all cases with acetabular dysplasia, pressure on the femoral head caused by muscle tension is transmitted concentrically to the small localized contact area of the femoral articular surface and may cause a continuous shearing stress on the medial longitudinal trabeculae of the femoral head, resulting in their destruction. Moreover, during walking, an instability of the hip joint causes abnormal

friction between the two small articular surfaces which may exert an extremely strong intermittent shearing stress on the medial longitudinal trabeculae in the femoral head. All these abnormal mechanical factors may cooperate in the causation of the complicated degenerative changes in the hip joint.

Trabecular Architecture of the Upper End of the Femur

The results of experimental and clinical studies on the development of osteoarthritis of the hip prompted the authors to attempt a study on the trabecular architecture of the upper end of the femur. For this study, thirty specimens of the normal human femur were sliced parallel in the frontal plane. In these specimens, the angle which the medial longitudinal weight-bearing trabecula passing through the center of the femoral head forms with the longitudinal axis of the shaft was measured roentgenologically (Figure 9). It was found to be about 22°. Further photoelastic experiments were carried out to elucidate the function of the transverse trabeculae arising from the lateral cortex below the greater trochanter and running to the femoral head (Figures 10 A and B). The tensile force in the upper part of the femoral neck induced by a vertical load on the femoral head as indicated by the arrow in Figure 10 A is eliminated by a load acting on the greater trochanter in the direction of the gluteal muscle which is less than one half of the load on the femoral head as shown in Figure 10 B. In



Figure 9 Roentgenogram showing the trabecular architecture of the upper end of the femur. The medial longitudinal trabecula which bears the body weight forms an angle of approximately 22 degrees with the longitudinal axis of the shaft.

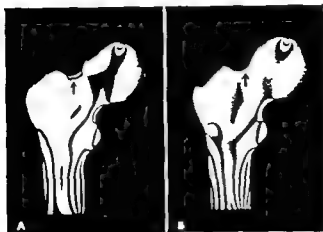


Figure 10 Photoelastic study on the mechanical stress induced by loads acting on the upper part of the femur A tensile force at the upper part of the femoral neck induced by a vertical load acting on the femoral head as indicated by the arrow in Figure 10 A is eliminated by a load acting on the greater trochanter in the direction of the gluteal muscles which is less than one half of the load on the femoral head as shown in Figure 10 B

the normal hip the pressure of more than one half of the load on the femoral head is thought to act on the greater trochanter in the direction of the gluteal muscle while standing and walking. It was proved by these photoelastic experiments that the transverse trabeculae also bear the transverse pressure produced by the abductor muscles, rotator muscles, tensor fasciae latae muscle, and also adductor muscles which presses the femoral head against the acetabulum. From these facts it is evident that the trabecular architecture of the upper end of the femur is also constructed on the basis of the following general principles of bone formation. The line of the bony trabeculae corresponds to the line of maximal pressure. Further the trabeculae are thickest and most closely packed where the stress is greatest. The medial longitudinal trabeculae are thickest and most numerous and bear the greater part of the load on the joint. On the other hand these long trabeculae are thought to offer the least resistance to shearing stress. It would therefore appear that in the hip with acetabular dysplasia the articular surfaces are worn down by friction and the medial longitudinal trabeculae are broken by shearing stress, resulting in destructive changes combined with reactive new bone formation around the femoral head and upward migration of the femoral head.

*Principles of Operative Treatment for Osteoarthritis of the Hip with
Incongruity between the Articular Surfaces*

On theoretical grounds the results of the studies mentioned above warrant the following principles of operation for osteoarthritis of the hip secondary to acetabular dysplasia (Figures 11-A B C and D)

1 In early osteoarthritis of the hip with marked acetabular dysplasia in which the articular cartilage is well preserved the affected joint is reconstructed into a mechanically stable condition by a shelf operation combined with a muscle release operation around the hip (Figures 11 A and B) In this case innominate osteotomy may also be indicated on the basis of the same principle

2 In cases with acetabular dysplasia and deformities of the femoral neck or upward migration of the femoral head from the center of the acetabulum combined with formation of medial osteophyte the affected joint is reconstructed into the mechanically stable condition by combination of the shelf operation varisation or valgisation of the femoral neck and medial displacement of the shaft (Figures 11 C and D) Parti-



Figure 11 Diagrams showing principles of operative procedures for osteoarthritis of the hip secondary to acetabular dysplasia. In the hip with acetabular dysplasia a load on the femoral head is transmitted through a point medial to the center of femoral head. The small localized articular surfaces are subjected to a strong friction and the medial longitudinal trabeculae to a shearing stress (A). By shelf operation these abnormal mechanical stresses are eliminated and the weight transmitting areas of the articular surfaces increase in size. Moreover the joint is decompressed by release of the muscles around the hip (B). Furthermore as shown in C and D the joint is reconstructed into the mechanically stable condition by various combinations of the shelf operation varisation (C) or valgisation (D) of the femoral neck, medial displacement of the shaft and release of the muscles about the hip. Particularly by valgisation of the femoral neck, the medial longitudinal trabeculae are made erect, resulting in elimination of the shearing stress acting on them.

cularly as seen in Figure 11 D when the femoral neck is placed in a valgus position by osteotomy the medial longitudinal trabeculae are made erect and in consequence they are completely released from the shearing stress. This procedure should be followed by a muscle release procedure to reduce the excessive pressure on the joint. Bone grafting in a large cyst promotes repair.

Technique of the Shelf Operation and Release of the Muscle about the Hip

The shelf operation should be performed with an exact technique. The Smith Petersen anterior iliofemoral skin incision is usually used. The attachments of the gluteus medius and minimus muscle and tensor fasciae latae muscle are severed from the iliac crest and the gluteal muscles are subperiosteally stripped from the external surface of the ilium. The reflected tendon of the rectus femoris muscle is also dissected. Then the joint capsule is opened and the site where the shelf is to be created is determined under direct vision. Next two bone plates and several small bone chips are taken from the outer table of the ilium. A bone plate concave in shape and of size adequate to cover the portion of the femoral head which projects beyond the acetabulum is inserted deeply into the acetabular rim in a semicircular line conforming to the natural curve of the acetabulum. Then the second bone plate is bridged between the first bone plate and the outer table of the ilium. Several bone chips are placed in the triangular space surrounded by the two bone plates and the ilium. The abductor muscles and tensor fasciae latae muscle are reattached to the ilium in a relaxed state. Subsequently open adductor tenotomy is carried out. No plaster cast is applied. After operation skin traction of the involved leg up to four kilograms is maintained for four weeks. Thereafter the patient is encouraged to perform exercises of the affected limb and is allowed up on crutches.

MATERIALS

Since 1949 50 osteoarthritic hips of 48 patients (44 females and 3 males) aged 19 to 57 years (mean 32) have been surgically treated in accordance with the principles described in the foregoing. In this series the shelf operation combined with release of the muscles about the hip was performed in 33 hips and various combinations of shelf operation, varisation or valgisation of the femoral neck and medial displacement of the femoral shaft by intertrochanteric osteotomy and release of the muscles about the hip were carried out in 15 hips.

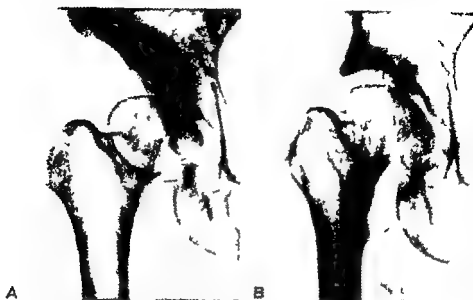


Figure 12 Case 1 A an early stage of osteoarthritis of the hip with formation of cyst in the degenerative acetabular roof B three years after the shelf operation combined with release of the muscles around the hip

RESULTS

The patients were followed up for two to seven years (average three and a half years). So far good results have been obtained in all cases. In most cases pain of the affected hip disappeared two to six months after operation. However limp due to weakness of the muscles about the hip persisted for more than six months after the operation. Roentgenographically the shelf created was replaced by new bone within six months after operation. The degenerative changes in the affected joint were gradually repaired in the course of one to two years. In advanced cases in which the shelf operation was carried out in combination with medial displacement of the femoral shaft and varisation or valgisation of the femoral neck numerous thickened vertical longitudinal trabeculae were formed in the femoral head and the cartilage space also increased in width. The range of motion of the involved hip decreased to some degree in some cases but this was of little concern as the patients were relieved of pain.

CASE REPORT

- 1 Shelf operation combined with release of the muscles about the hip
Case 1 H1 a woman 29 years old with progressive pain of the left hip since



Figure 13 Case 2 A osteoarthritis of the dysplastic hip with deformity of the femoral head and cyst in its lateral part B three years after the shelf operation combined with release of the muscles around the hip

she was the age of 24. There was no limitation of motion. X-ray showed marked acetabular dysplasia with formation of a cyst (Figure 12 A) but the cartilage space was well preserved. The shelf operation was performed with release of the muscles about the hip followed by skin traction of the affected leg for four weeks. Six months after operation the hip was painless and six months later the limp also disappeared. Roentgenograms made four years after operation showed that the shelf created at the proper site was organized well adapted to and supported the femoral head (Figure 12 B).

Case 2 F.H., a boy 19 years old with severe pain in the right hip for six months. He walked poorly with a stick. Examination revealed no limitation of hip motion. Roentgenograms showed a marked acetabular dysplasia and a mushroom shaped deformity of the femoral head with a cyst in its outer non weight bearing portion. However there was no narrowing of the cartilage space (Figure 12 A). The shelf operation was performed in combination with release of the muscles about the hip followed by skin traction of the involved leg for four weeks. One year after operation the patient was completely free from pain and weakness of the hip also disappeared. Roentgenograms made three years after operation revealed that the shelf was incorporated and well adapted to the femoral head. The cyst had almost completely disappeared (Figure 13 B).

2 Combination of shelf operation osteotomy and muscle release operation

(i) Combination of shelf operation varisation of the femoral neck and medial displacement of the shaft.

Case 3 N.S. a woman aged 50 years. Progressive pain in the right hip had begun

two years previously. Mobility of right hip flexion to 90 degrees abduction to 10 degrees adduction to 90 degrees and rotation zero. Roentgenograms showed a markedly dysplastic acetabulum an outward migration of the femoral head extensive cyst formation and a slight narrowing of the cartilage space (Figure 14 A) As may be seen in this figure several cysts are arranged in the oblique equatorial plane in the femoral head along which a shearing stress is thought to act. The shelf operation was carried out in combination with varisation of the femoral neck and medial displacement of the shaft by osteotomy. A long hip spica cast was applied and was worn for two months. Six months after operation the patient was relieved from pain and moreover weakness of the hip had also disappeared. There was no limitation of the hip motion. As seen in the roentgenogram (Figure 14 B) made seven years after operation the right hip was nicely reconstructed resulting in a remarkable restoration of the degenerative changes in both the bone and the articular cartilage. Numerous thickened vertical longitudinal trabeculae formed in the femoral head during these seven years. This suggests that a load on the femoral head is vertically transmitted along the longitudinal trabeculae to the shaft. This shows that the trabecular architecture in the femoral head had been reconstructed to adapt itself to the changes in mechanical condition caused by the operations mentioned above.

In this case the restoration of the degenerative changes might have been obtained by varus osteotomy alone valgus osteotomy combined with release of the muscles alone or also by oblique displacement osteotomy alone.



Figure 14 Case 3 A osteoarthritis of the dysplastic hip with several cysts arranged in the oblique equatorial plane of the femoral head B seven years after the reconstructive operation and medial displacement of the femoral shaft



Figure 15 (case 4) A an osteoarthritic hip with marked acetabular dysplasia and varus anteversion deformity of the femoral neck. B five years after combined operations of shelf operation valgisation and derotation of the femoral neck medial displacement of the shaft and muscle release operation

- (ii) Combination of the shelf operation valgisation of the femoral neck and medial displacement of the shaft by osteotomy and release of the muscles around the hip

CASE 4 VI a woman 70 years old with dull pain in the left hip. There was no limitation of the hip motion. Roentgenograms revealed a marked dysplasia of the acetabular roof and an extreme varus anteversion deformity of the femoral neck. However no narrowing of the cartilage space was found (Figure 15). The shelf operation was carried out in combination with valgisation and derotation of the femoral neck and medial displacement of the shaft by intertrochanteric osteotomy. Tenotomy of the adductor muscles was not performed because they were relaxed by medial displacement of the shaft. However the abductor muscles were released because they were stretched by valgisation of the femoral neck. The limb was immobilized in a long hip spica cast for two months. The patient was relieved from pain and weakness of the hip disappeared six months after operation. Roentgenograms made six years after operation revealed that the affected hip was reconstructed into the mechanically stable condition (Figure 15). As seen in this figure the longitudinal trabeculae in the femoral head are thick compact and radiate proximally from the lesser femoral of the femoral neck in a fan like fashion. If it is indeed true that form follows function this region morphologically suggests that a load placed superiorly on the femoral head is transmitted concentrically to the lesser femoral of the femoral neck. This fact was also proved by a phot

study (Figure 16) Therefore the longitudinal trabeculae in the femoral head are completely released from the shearing stress

Case 5 C.T. a woman 57 years old had had pain in the right hip for five years It became progressively worse in degree and duration Right hip motions were flexion to 60 degrees abduction to 15 degrees adduction to 15 degrees and rotation zero Roentgenography showed a marked acetabular dysplasia calcification of the joint capsule covering the lateral part of the femoral head narrow cartilage space and mushroom shaped deformity of the femoral head with a medial osteophyte and a large cyst in the lateral part (Figure 17) In this case combined operations composed of the shelf operation bone grafting in the cyst valisation of the femoral neck and medial displacement of the shaft by intertrochanteric osteotomy and release of the abductor muscles were carried out A long hip spica cast was applied and was worn for two months She was relieved from pain four months after operation Weariness of the hip also disappeared five months later Roentgenograms made four years after operation showed a marked restoration of the degenerated areas (Figure 17 B) As may be seen in this figure the shelf created united with the calcified joint capsule and adapted itself to the femoral head The cyst in the femoral head subsided and cartilage space increased in width

Case 6 M.M. a woman 51 years old has had increasing pain in the right hip for ten years She walked poorly with a stick Right hip flexion to 80 degrees abduction to 10 degrees adduction to 20 degrees and rotation zero Roentgenography showed a mushroom shaped deformity of the femoral head with its outward migration from the center of the acetabulum accompanied by formation of a large medial osteophyte and a large cyst in the lateral non pressure portion of the head There was almost complete obliteration of the cartilage space (Figure 18 A) In this case



Figure 16 Case 4 Photoelastic study shows that a vertical load acting on the femoral head is transmitted concentrically to the cal or femoral of the femoral neck



Figure 17 Case 3: A advanced osteoarthritic hip with acetabular dysplasia calcification of the joint capsule covering the lateral part of the femoral head mushroom shaped femoral head having a large cyst and medial osteophyte and narrowing of the cartilage space B four years after combined operations i.e. shelf operation bone grafting in the cyst valgisation of the femoral neck medial displacement of the shaft and release of the muscles

combined operations composed of the shelf operation bone grafting in the cyst, and valgisation of the femoral neck and medial displacement of the shaft by intertrochanteric osteotomy were carried out (Figures 18-B). Moreover the abductor muscles were released. The limb was immobilized in a long hip spica cast for two months. The patient was relieved from pain six months after operation. Stability of the hip was also gradually regained in the course of one year thereafter. Roentgenograms made five years after operation showed marked restoration of the degenerative changes (Figure 19). As may be seen in this figure the shelf created at the proper site was replaced with new bone and adapted itself to the femoral head and the cartilage space increased in width. In the femoral head the cyst was repaired and the longitudinal trabeculae placed in the vertical position markedly increased in number and thickness while decalcification occurred in the medial osteophyte. In this reconstructed joint it is suggested that a load on the femoral head is transmitted vertically along the longitudinal trabeculae to the shaft and in consequence the medial osteophyte is released from mechanical stress. It is evident that the improvement of the mechanical condition in the joint combined with reduction of pressure caused by muscle tension resulted in reconstruction of the longitudinal trabeculae in the femoral head and decalcification of the medial osteophyte.



Figure 18 Case 6 A osteoarthritic hip with an outward migration of the femoral head from the center of the acetabulum accompanied by formation of a large medial osteophyte and a large cyst in the lateral portion of the femoral head and almost complete obliteration of the articular space B diagram showing the combined procedures composed of the shelf operation bone grafting in the cyst calcification of the femoral neck medial displacement of the femoral shaft and muscle release operation

DISCUSSION

In this paper the biomechanism responsible for development of osteoarthritis in the dysplastic hip was considered on the basis of the results from clinical and experimental studies and also the study of the architecture of the trabeculae in the upper end of the femur. From the results obtained the basic principles were defined for operative treatment for various types of osteoarthritis of the dysplastic hip.

It is supposed that in cases with acetabular dysplasia not only an excessive pressure on the small localized articular surfaces but also a shearing stress acting on the longitudinal trabeculae of the femoral head plays an important role in the development of degenerative changes in the joint. Pathological changes which are thought to be caused by shearing stress on the longitudinal trabeculae are clearly seen in Cases 2 (Figure 13 A) 3 (Figure 14 A) 5 (Figure 17 A) and



Figure 19 Case 6 five years after operation

6 (Figure 18 A) In cases 2, 5 and 8 the cyst is located in the lateral part of the femoral head which is subject to least pressure. In Case 11 several cysts are arranged in the oblique equatorial plane along which a shearing stress is thought to act.

In early cases with marked acetabular dysplasia it was shown that the shelf operation if it is performed with an exact technique and is combined with the muscle release procedure, arrests progress of degenerative changes in the joint and promotes its regeneration. In nine advanced cases the joint was reconstructed by a combination of the shelf operation, valgisation with or without derotation of the femoral neck, medial displacement of the shaft and the muscle release procedure. In three other advanced cases the joint was reconstructed by a combination of the shelf operation, varisation of the femoral neck, medial displacement of the shaft and the muscle release procedure. In all these cases the pathological changes were repaired and numerous thickened vertical longitudinal trabeculae were reconstructed.

By means of the shelf operation the contact areas of the articular surfaces increase in size, resulting in wide distribution of the load over the femoral head. By valgisation of the femoral neck the longitudinal

trabeculae are released from shearing stress. By variation of the femoral neck the contact areas of the articular surfaces increase in size and the load on the femoral head is reduced due to relaxation of the muscles about the hip. However the essential procedure for reconstruction of the dysplastic hip into the mechanically stable condition is the shelf operation combined with medial displacement of the shaft and release of the muscles about the hip by which the load on the femoral head is reduced distributed widely over the femoral head and transmitted vertically to the shaft. Under this condition numerous thickened vertical longitudinal trabeculae are formed in the femoral head even though the femoral neck is placed in the varus position as shown in Case 3 (Figures 14 A and B).

The gains from cutting the bone angulation and displacing the shaft are well documented but the mechanism of pain and the reversal of the degenerative process is still obscure. The procedures advocated by *McMurray Pauwels* and *Voss* are in fact variations of one procedure which must be modified according to the clinical and roentgenological findings. It is a mistake to use a stereotype technique for all patients. It is not realistic to expect one operation to be best for all of them. Though the greatest usefulness of the *Voss* temporary hanging hip procedure is for a patient too old to withstand major surgery or with advanced arthritis of the hip and a range of hip motion too small to justify other procedures this procedure is used also in combination with the shelf operation and valgisation of the femoral neck as shown in the cases presented here. Though *Pauwels* varus osteotomy gives an excellent result in patients with acetabular dysplasia accompanied by coxa valg luxans the shelf operation combined with the muscle release procedure is also useful in patients with acetabular dysplasia too excessive to justify varus osteotomy.

The results obtained in our studies revealed that the shelf operation combined with the muscle release procedure is applicable to the early case with marked acetabular dysplasia and that the shelf operation combined with medial displacement of the shaft and muscle release procedure is applicable to advanced case. Furthermore in these latter cases variation or valgisation of the femoral neck can be additionally done according to the clinical and roentgenological findings.

SUMMARY

1 The principles of treatment for osteoarthritis of the hip with no congruity were described. On the basis of the principles the affected

hip was reconstructed into the mechanically stable condition by various combinations of the shelf operation varisation or valgisation of the femoral neck medial displacement of the shaft and muscle release operation in 50 cases. In all cases good results were obtained.

¶ In 38 early cases with a marked acetabular dysplasia the shelf operation was performed in combination with release of the muscles about the hip.

¶ In 12 advanced cases with a marked acetabular dysplasia and deformities of the femoral head and neck the affected hip was reconstructed into the mechanically stable condition by combination of the shelf operation intertrochanteric osteotomy and release of the muscles about the hip through which a load on the femoral head is reduced distributed widely over the femoral head and transmitted vertically to the shaft.

RÉSUMÉ

1 Il est donné la description des principes du traitement de l'ostéoartrite de la hanche. Sur la base de ces principes la hanche a été reconstruite dans 50 cas de manière à obtenir une condition mécanique stable par différentes opérations combinées: butée complétant le toit du cotyle varisation ou valgisation du col fémoral déplacement médial du corps fémoral et relâchement des muscles. De bons résultats ont été obtenus dans tous les cas.

2 Dans 38 cas précoces avec dysplasie marquée du cotyle l'opération de butée du toit a été pratiquée en combinaison avec le relâchement des muscles autour de la hanche.

3 Dans 12 cas avancés avec dysplasie marquée du cotyle et déformité de la tête et du col du fémur la hanche atteinte a été reconstruite de manière à obtenir une condition mécanique stable par une opération combinée de butée du toit du cotyle d'ostéotomie intertrochantérienne et de relâchement des muscles autour de la hanche grâce à laquelle la charge sur la tête fémorale est réduite du fait qu'elle est plus largement répartie et transmise verticalement au corps du fémur.

ZUSAMMENFASSUNG

1 Die Prinzipien der Behandlung der osteoarthritischen inkongruenten Hüfte werden beschrieben. Auf Grundlage dieser Prinzipien wurde die erkrankte Hüfte mittels verschiedener Kombinationen von Pfannendachoperationen Varus- und Valguseinstellung des Schenckelschafts medialer Schaftverschiebung und Muskelumlagerungen in 50 Fällen

len in eine mechanisch stabile Verfassung gebracht. In allen Fällen wurden gute Resultate erzielt.

2. In 38 frühzeitigen Fällen mit ausgesprochener Acetabulardysplasie wurde die Pfannendachplastik in Kombination mit der Auflösung der Muskeln der Hüftregion ausgeführt.

3. In 12 vorbeschriebenen Fällen mit ausgesprochener Acetabulardysplasie und Deformitäten des Femurkopfes und Halses wurde in der erkrankten Hüfte mittels Pfannendachplastik intertrochanter Osteotomie Muskelauflösung der Hüftregion ein mechanisch stabiler Zustand wiederhergestellt durch den die Belastung des Femurkopfes verringert, weit über den Femurkopf verteilt und vertikal auf den Schaft überführt wird.

REFERENCES

1. Adam A. & Spence A. J. (1958) Intertrochanteric osteotomy for osteoarthritis of the hip. *J Bone Jt Surg* 40 B 219-226.
2. Blount W. P. (1964) Osteotomy in the treatment of osteoarthritis of the hip. *J Bone Jt Surg* 46 A 1297-1325.
3. Hackenbroch W. (1957) Die Arthrosis deformans des Hüftgelenkes. Beilage *Zsch Orthop* 88. In Verhandlungen der Deutschen Orthopädischen Gesellschaft 43. Kongress 23-59.
4. Knodt H. (1964) Osteoarthritis of the hip joint. Etiology and treatment by osteotomy. *J Bone Jt Surg* 46 A 1326-1336.
5. McMurray T. P. (1935) Osteoarthritis of the hip joint. *British J Surg* 22 716-727.
6. McMurray T. P. (1939) Osteoarthritis of the hip joint. *J Bone Jt Surg* 21 1-11.
7. Nakamasu M. Study on the trabeculae architecture of the upper end of the femur and its function. (In press).
8. Nicoll E. A. & Holden N. T. (1961) Displacement osteotomy in the treatment of osteoarthritis of the hip. *J Bone Jt Surg* 43 B 56-60.
9. Nakas M. (1960) Zur operativen Behandlung der Arthrosis deformans des Hüftgelenkes. *Zbl Chir* 85 362-367.
10. Osborne G. A. & Fahrme W. H. (1950) Oblique displacement osteotomy for osteoarthritis of the hip joint. *J Bone Jt Surg* 32 B 143-160.
11. Ottolenghi C. F. & Frigerio Edgar (1962) Intertrochanteric osteotomies in osteoarthritis of the hip. Fundamental indications, techniques and results. *J Bone Jt Surg* 44 A 855-896.
12. Pauwels J. M. (1950) Über eine kausale Behandlung der Coxa valga luxans. *Zsch Orthop* 79 303-315.
13. Pauwels J. M. (1971) Neue Richtlinien für die operative Behandlung der Koxarthrose. Beilage *Zsch Orthop* 91. In Verhandlungen der Deutschen Orthopädischen Gesellschaft 48. Kongress 332-367.
14. Voss C. (1956) Koxarthrose - Die temporäre Hängehüfte. *Münchener Med Wochenschr* 98 934-937.
15. Yokosaki M. (1964) Experimental study on osteoarthritis of the hip joint secondary to acetabular dysplasia. *J Jap Orthop Ass* 38 1-2.

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INTERTROCHANTERIC VALGUS OSTEOTOMIES IN HIP ARTHROSIS

By

BENGT TILLBERG

Received 23 vi 67

Surgery in hip arthrosis is a problem with many facets and a problem which is very far from being solved. At the Orthopaedic Clinic in Harnösand arthrodesis is considered to be a method which gives good results (11) but it is in many hands an operation with infrequent bone union. Furthermore this arthrodesis has limited indications (11-13) and thus there remain many patients with coxarthrosis who must be treated in other ways. A simple method which has attracted much interest is the intertrochanteric valgus osteotomy which was introduced by Lorentz (12) and developed by McMurray (14). This technique used to be complicated by the long period of after care owing to the plaster fixation and the consequent increased rigidity of the patient. In the last decade conditions have improved owing to the use of internal fixation (2, 8, 10, 21) and the method has regained its popularity. A number of follow up surveys have also been published but the majority of these show a miscellaneous range of etiologies and only a small number are comprised solely of coxarthrosis cases (7). To confuse the issue further some of the reported cases had been treated by conventional plaster fixation (3, 13, 14, 16, 22) some by both internal fixation and plaster (18) and yet others by a mixture of either internal fixation or plaster (1, 15, 20). Therefore the author thought it important to publish the results of a series of operations performed on clear coxarthroses in which internal fixation without plaster was used followed by uniform after care of the patient.

In the published surveys there is a large divergence in the methods of reporting results which makes comparisons difficult. Gade (6) introduced a standard assessment procedure which has been developed

and used by Shephard (19 20). A more recent follow up survey of conservatively treated hip arthroses has employed the same assessment index (5).

MATERIAL

This series is based on patients with primary idiopathic arthrosis or secondary arthrosis owing to epiphyseolysis for which it was not possible to make a differential diagnosis. In the period 1955-60 operations were performed on 115 patients in the age range 39 to 71 years (average 56 years). A total of 194 valgus osteotomies were performed with the same technique as 9 patients were operated on bilaterally. Different operative techniques have been employed in the treatment of the contra lateral joints of 10 patients as can be seen in Table 1. The sex distribution is fairly even with 63 male and 61 female hips and 70 of the patients had bilateral arthrosis. Before the operation the patients had pain for an average period of more than 4 years. 8 patients died, one of these post-operatively owing to a cerebral embolism while 7 died several years later from causes not connected with the operation. All the remaining patients were examined by the author after a minimum post-operative period of 5 years (average period 6.5 years). The results are reported both according to subjective, objective and radiological assessment and also employing the index of Gade (6).

Table 1

	Male	Female	Numbers
Unilateral osteo arthritis with osteotomy	27	27	54
Bilateral osteo arthritis	Unilateral osteotomy	21	51
	Bilateral osteotomy	5	9
	Other side other operation	8	10
Sum	63	61	124

Arthrodesis 1 Smith Petersen 4 Girdlestone 2 Moore 3

INDICATIONS AND OPERATIVE PROCEDURE

The main indications were aching at rest and pain on weight bearing. In addition relatively good mobility was required, i.e. flexion capacity of at least 60 degrees (13) and an adduction capacity corresponding to the intended valgus position (16 23). After the introduction of varus osteotomies X-rays are taken to an ever increasing extent both in abduction and adduction (17) in order that operative procedure could be modified to produce the best congruence between caput and acetabulum.

Via an incision 5 inches long, and an approach through the posterior portion of vastus lateralis the shaft of the femur and the intertrochan



Figure 1 a and b Diagram of operative procedure and radiological appearance of the completed valgus osteotomy

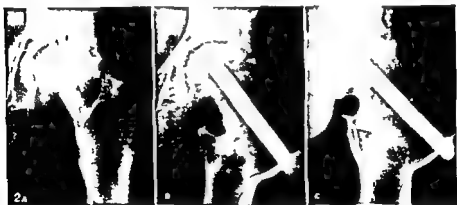


Figure 2 Radiological appearance of the arthrosis hip a) pre-operatively b) 3 months post operatively and c) 7 years post operative!

teric line were exposed. Very often a wedge was excised as shown in Figure 1 a (2) with a lateral base in accordance with the planned valgus position. The wedge was also designed to afford correction of the flexion contracture. Afterwards the rotation malposition was corrected and the medial displacement of the distal fragment was performed. In the present series this medial displacement extended to the width of the cortex in 23 cases, up to half the diameter of the femur in 67 operations and more than half the diameter of the femur in the remaining cases.

Before internal fixation was introduced plaster fixation was used. In the mid fifties the Kessel plate (9) was employed in a few cases (Table 2) but late in 1955 the method of Mckeel Nissen (10, 21) was adopted—i.e. fixation with plate and nail of Figure 1 b. Despite the rigid fixation which prevents the maintenance of compression between caput fragment and shaft following resorption (23) the method has been proved neither to be a disadvantage nor to endanger healing. This is perhaps due to the fact that the nail is given an extra blow before the nut is tightened so substantial compression is obtained in this way in valgus osteotomies.

Postoperative care regularly consisted of 6 weeks bed rest and physiotherapeutic treatment of the knee was instituted 3 weeks postoperatively. After 6 weeks the patients were allowed up on crutches and systematic walking exercises were begun and training for the activities of daily living. After a total of a couple of months in hospital the patients were allowed to go home with continued exercise schedules but out patient physiotherapy was continued only in a few cases.

Complications There were 8 cases of postoperative hematoma with delayed healing, infection superficially at the site of operation in 2 cases and thrombosis in 10 cases. Bronchial pneumonia occurred in 3 cases and there was also a fatality owing to cerebral hemorrhage.

RESULTS

Initially plaster fixation was used and afterwards for a short period the Kessel plate before the nail and plate procedure of Mckeel Nissen was adopted. During the period 1955-60 which this survey covers 6 patients were treated by plaster fixation alone. 13 operations were performed with the Kessel plate but in the majority of these cases the valgus position sought could not be maintained and in 8 of the cases with the Kessel plate instability compelled us to apply plaster in ad-

Table 2

Fixation	Numbers	Pseudo arthrosis	Ankylosis	Failures
Plaster only	6	1	2	4
Kessel	13	2	0	2
plate		4	1	5
+ plaster		8	0	1*
Nail plate a.m. Mckeel Nissen	97	8	0	1*

dition (Table 2) 5 of these cases with plaster fixation suffered thrombosis postoperatively and 11 of the above 19 cases were not successful as their discomfort was not alleviated 7 developed into pseudoarthroses and 3 cases healed primarily as arthrodesis i.e. considered unsuccessful as osteotomies. Therefore as 58 per cent of these 19 cases were not successful the need for better internal fixation by nail and plate was obvious. In order to obtain a series consisting solely of coxarthroses operated upon in a uniform way and with fixation by nail and plate ad modum McKee-Nissen the above 19 cases have been excluded from the following account.

Therefore in 97 hip operations of valgus type utilizing McKee-Nissen fixation 70 per cent of the patients consider that the operation was worth performing 18 per cent were satisfied but had reservations as they thought that their mobility had become worse or that they had become weaker in the leg, after the operation 12 per cent dissatisfied with the result of the operation 3 because other troubles had arisen in the back and knee and 9 cases because their troubles were just as pronounced as before the operation 16 per cent were completely pain free while a further 42 per cent had insignificant discomfort not affecting their activity but noticeable after extreme weight bearing or change of weather. Weight bearing pain alone occurred in 9 per cent and aching only at rest in 3 per cent but in all cases the pain was considerably less than before the operation 30 per cent continued to have both weight bearing pain and aching at rest but 18 per cent of these were considerably better than they were before the operation. No change had occurred in 12 per cent of the cases where the operation must therefore be regarded as unsuccessful. Thus 88 per cent of the patients felt some improvement after operation as is shown in summarized form in Table 3 where the results are reported according to the Gade index.

Table 3 Pain (in groups according to Gade)

	<i>n</i>
Excellent	50
Good	23
Fair	10
Poor	12

7 of the 12 unsuccessful cases (12 per cent) were reoperated on by another method 4 cases of arthrodesis 2 endoprostheses ad modum Moore and 1 case of arthroplasty ad modum Smith-Petersen. At the follow up these patients could not be recorded as osteotomies and

therefore the clinical as well as the radiological findings presented here will cover only 90 hip operations

In general the patients themselves were allowed to decide when they could dispense with the aid of sticks after the operation. 12 patients stopped using sticks within 6 months, 24 patients used sticks for between 6 and 12 months and 14 patients stopped using sticks after a period of more than 1 year. In all, 56 per cent did not use sticks at the time of last examination. 25 of the remaining 44 per cent who continue to use sticks had bilateral arthrosis and 10 of them had been operated on bilaterally. Trendelenburg's tests were negative in 53 per cent, doubtful in 30 per cent and clearly positive in 17 per cent. 98 per cent could unaided and 98 per cent could cope with personal hygiene and shoes unaided and 98 per cent could cope with personal hygiene

Table 4 Ability to work

	%
None	43
Clerical work	5
Homework	34
Industrial work	11
Heavy work	7

Table 5 Restriction of functional activity

	%
Mild	41
Moderate	46
Severe	13

Many of the patients who had previously done heavy work in agriculture, forestry or industry could not perform similar work in spite of the operation. At the time of follow up 57 per cent had wage earning work and of these 5 per cent did their work while sitting, 34 per cent had lighter work mainly as housewives, while 11 per cent still had fairly heavy industrial work and 7 per cent heavy agricultural and forestry work (Table 4). Of the remaining 43 per cent who did not work, 9 per cent were too old to work and 34 per cent were retired with an early pension owing to the hip trouble. Summarizing Table 5 shows restriction of function according to the Gade index, i.e. the ability to cope with the activity of daily living including Trendelenburg, the use of sticks and the capacity to work.

Initially the indications were not completely clear but developed as

our experience of the operation increased thus a number of patients which did not fulfill the previously stated conditions were operated on. It was found at the follow up that of the 12 unsuccessful operations 7 cases had adduction contractures before the operation 5 had no adduction ability and 5 had flexion of less than 60 degrees. Clinical examination showed that 60 cases had flexion contractures before the operation and that 80 per cent of these had been corrected. 35 out of 45 outward rotation malpositions were corrected while 14 new ones developed post-operatively so that in all outward rotation contractures were present in 27 per cent following the operation. The changes which took place with respect to mobility are shown in Table 6. These changes were generally slight and the mean value of the Gade index rose from 45 before the operation to 50 at the time of follow up. This increase is not statistically significant and therefore one cannot expect to be able to increase the mobility appreciably by this operation. It is very important to be aware of this when a patient is informed pre-operatively of the result which can be justifiably expected from the operation. This was also shown at the follow up when 12 patients declared themselves to be less pleased with the operation because their mobility had become worse than they expected. The range of motion before and after the operation is summarized in Table 7 in terms of the Gade index.

Table 6 Changes in mobility by the operation in per cent

After operation	Increased	Unchanged	Decreased
Flexion	30	36	34
External rotation	23	52	25
Abduction	51	39	10
Adduction	33	47	19

Table 7 Range of motion (according to Gade)

Mobility before operation	Mobility after operation				Sum in %
	Excellent	Good	Fair	Poor	
Excellent	31	5	0	0	37
Good	22	17	8	2	57
Fair	11	2	0	1	14
Poor	0	1	0	1	2
Sum in %	59	23	9	4	100

Table 8 Radiographic changes in per cent

	Better	Unchanged	Worse
Joint space	56	29	15
Cysts	50	23	27
Sclerosis	23	57	20
Osteophytes	0	51	49

X rays conventionally analysed showed improvement in the joint space in 56 per cent of the cases (Table 8) (1 18 20). There were healed cysts in 50 per cent and diminished sclerosis in 23 per cent. It was shown radiologically that the arthrosis process which is usually seen to progress in untreated hips ceased after the operation and sometimes healed to a large extent (see Figures 2 a-c).

The nail plate and screws were of stainless steel but owing to the discomfort caused by electrolytic action (4) we were compelled to extract these implants in 43 per cent of the cases. Of the remaining 57 per cent who retained their osteosynthesis material about half had tenderness at the site of operation. As this also was probably caused by electrolytic action around plate and nail consideration was given to changing to titanium implants. Unfortunately plates of this material cannot readily be bent and this is just what one is sometimes compelled to do in order to adapt the valgus angle to the adduction ability and anatomical conditions of each patient and also to make possible the medial displacement of the distal fragment.

SUMMARY

Valgus intertrochanteric osteotomies were performed on 97 patients with hip joint arthrosis and fixation was achieved by plate and nail according to McKee-Lissen. These operations were carried out in the Orthopaedic Clinic in Harnosand in the period 1955-60 and the follow up was undertaken on average 6.5 years postoperatively.

Improvement as regards aching at rest and weight bearing pain was present in 88 per cent of the cases. 57 per cent had resumed work of some form and 87 per cent demonstrated the ability to cope with daily living. On the other hand mobility was scarcely affected by the operation. As determined radiologically the arthrosis process was found to have ceased and there were increased joint spaces and healed cysts in half of the cases.

RESUME

Des osteotomies intertrochantériennes valgus ont été pratiquées chez 97 malades souffrant d'arthrose de la hanche

La fixation a été accomplie au moyen de plaques et de clous d'après la méthode McKeen Nissen

Ces opérations ont été effectuées à la Clinique Orthopédique de Hårnösand dans la période 1955-60 et les examens complémentaires ont été entrepris en moyenne 8 ans et demi après l'opération

On a constaté une amélioration en ce qui concerne les douleurs tant au repos que provoquées par le port d'un poids dans 88 pour cent des cas 57 pour cent avaient une certaine forme de travail 87 pour cent ont montré qu'ils étaient capables de vivre à peu près normalement La mobilité avait d'ailleurs à peine été affectée par l'opération Comme déterminé par la radiographie on a trouvé que le processus de l'arthrose s'était arrêté et qu'il y avait des espaces interarticulaires plus larges et des cystes guéris dans la majorité des cas

ZUSAMMENFASSUNG

Intertrochantersche Valgusosteotomien wurden an 97 Patienten ausgeführt deren Hüftgelenk mittels Platte und Nagel gemäss McKeen Nissen fixiert worden war Diese Operationen wurden in der orthopädischen Klinik in Harnösand während des Zeitraumes 1955-60 ausgeführt und die Nachuntersuchung wurde durchschnittlich 6 5 Jahre der Operation vorgenommen

Besserung hinsichtlich Ruheschmerz und Belastungsschmerz war in 88 Prozent der Fälle vorhanden 57 Prozent hatten Arbeit in irgend welcher Form wieder aufgenommen und 87 Prozent zeigten die Fähigkeit das tägliche Leben zu bewältigen Andererseits war die Beweglichkeit kaum beeinflusst durch die Operation Röntgenologisch wurde gefunden dass der arthrotische Prozess aufgehört hatte und dass erweiterter Gelenkraum und geheilte Cysten in der Hälfte der Fälle gesehen werden konnte

REFERENCES

- 1 Adam A & Spence A J (1958) Intertrochanteric osteotomy for osteoarthritis of the hip *J Bone Jt Surg* 40B 219-226
- 2 Blount W P (1943) Blade plate internal fixation for high femoral osteotomies *J Bone Jt Surg* 25 319-339
- 3 Campbell J P & Jackson J P (1956) Treatment of osteoarthritis of the hip by osteotomy *J Bone Jt Surg* 38B 473-474

- 4 Clarke E. G. C. & Hickman J (1953) An investigation into the correlation between the electrical potentials of metals and their behaviour in biological fluids *J Bone Jt Surg* 35B 467-473
- 5 Danielsson L. (1964) Incidence and prognosis of coxarthrosis *Acta orthop scand* Suppl III
- 6 Gade H (1947) Surgical treatment of osteo arthritis of the hip joint *Acta Chir scand* 85 Suppl 120
- 7 Harris N H & Kirwan E. (1964) The results of osteotomy for early primary osteo arthritis of the hip *J Bone Jt Surg* 46B 477-487
- 8 Hirsch C. (1957) Osteotomie i höftleden åter aktiva *Nord Med* 57 501
- 9 Jessel L. (1955) Discussion British Orthopaedic Association 1954 *J Bone Jt Surg* 37B 168
- 10 Lindström N C (1956) Personal communication
- 11 Lindström N G (1957) Partial intra plus juxtaarticular arthrodesis with simultaneous nailing according to Watson-Jones *Acta orthop scand* 26 255-269
- 12 Lorentz A (1925) Allgemeines über die Bifurkatia femoris und ihre Indikationen *Verh dtsch orthop Ges* 129-135
- 13 McFarland D (1954) My present attitude of osteo arthritis of the hip *J Bone Jt Surg* 36A 416-423
- 14 McMurray T P (1935) Osteo arthritis of the hip joint *J Bone Jt Surg* 27 716-727
- 15 Nicoll E A & Holden N T (1961) Displacement osteotomy in the treatment of osteo arthritis of the hip *J Bone Jt Surg* 43B 50-60
- 16 Osborne G N & Fahrni W H (1950) Oblique displacement osteotomy for osteo arthritis of the hip joint. *J Bone Jt Surg* 32B 148-160
- 17 Pauwels F (1960) Neue Richtlinien für die operative Behandlung der hox arthrose *Verh dtsch orthop Ges* 48 332-365
- 18 Robins H H C. & Piggot J (1960) McMurray osteotomy with a note on the regeneration of articular cartilage *J Bone Jt Surg* 42B 480-488
- 19 Shephard W (1954) Assessment of function after arthroplasty of the hip *J Bone Jt Surg* 36B 354-363
- 20 Shephard W (1960) A further review of the results of operations on the hip joint *J Bone Jt Surg* 42B(1) 177-204
- 21 Unander Scharin L. (1961) Arthrosis deformans coxae och dess operativa behandling *Nord Med* 63 345-350
- 22 Wardle E. N. (1955) Displacement osteotomy of the upper end of the femur *J Bone Jt Surg* 37B 568 575
- 23 Weber B G (1960) Zur Operationstechnik der McMurray osteotomie *Arch orthop Unfall Chir* 51 478-486

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CASE OF CHONDROSARCOMA WITH PULMONARY AND SKELETAL METASTASES AFTER HEMIPELVECTOMY, SUCCESSFULLY TREATED WITH ³⁵S SULFATE

By

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INTRODUCTION

In a recent paper in this journal (*Boström et al* 1968) the need for new methods of treatment of chondrosarcoma was discussed. On the basis of present knowledge of the biochemistry of these tumors the following two biochemical principles for the retardation of tumor growth were suggested: 1. Retardation of tumor growth by interference with the formation of its matrix *et al* by drug inhibition of the biosynthesis of sulfated glycosaminoglycans (*Boström et al* 1964) or by enhancing the breakdown of preformed cartilaginous matrix (*Thomas* 1956). 2. Introduction of a precursor which when built into the sulfated glycosaminoglycans will cause damage to the malignant cells. Both principles are related to the fact that sulfated glycosaminoglycans are important constituents of the matrices of such tumors and moreover that there is indication that the tumors have an increased formation rate of these compounds.

The approach of *Gottschalk et al* (1959 a b) *Andrews et al* (1960)

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A preliminary account of this work was given at the Annual Meeting of the Swedish Orthopedic Association Dec 1-4 1967, Stockholm, Sweden.

and *Bolstein & Marcus* (1963) who administered large doses of ^{32}S sulfate to patients with advanced chondrosarcoma exemplifies the utilization of the second of the two principles. The radioisotope was given in amounts of 0.6-1.2 C. With this dosage temporary arrest of growth and relief of pain were noted in several instances but in no case was a cure of the patient obtained. It was also established that the limiting factor in the therapeutic use of ^{32}S sulfate is the radiosensitivity of the hematopoietic system. Marked depression of bone marrow activity invariably followed the administration of the large doses of ^{32}S employed. However the marrow function was completely restored in about one month. Consequently the possibility of multiple courses of ^{32}S treatment for patients who respond well was suggested by *Bolstein & Marcus* (1963).

The purpose of the present paper is to report the effects of treatment with ^{32}S sulfate in an operated case of chondrosarcoma in which the principle of multiple courses referred to above was applied. In order to increase the ratio of exposure between tumor and bone marrow arterial injection of the isotope was used on some occasions. In this way it was possible to administer a total dose of radioactivity higher than any reported earlier, without protracted damage to the bone marrow. The result of the treatment was also more favorable. An apparent devitalization of a skeletal metastasis was obtained. There was also arrest of growth of pulmonary metastases.

CASE REPORT

Patient male aged 74 previously healthy with no family history of malignancy. In 1959 he complained of pain in the left gluteal region. Roentgenological examination early in 1960 revealed skeletal destruction in the tuberosity of the left ischium. The diagnosis of chondrosarcoma was verified histologically from biopsy material. In February 1960 a resection of the left ischium was performed at the Department of Orthopedic Surgery, Norrbacka Institutet and the tumor was regarded as radically removed. At the end of 1963 however local recurrence of the tumor was observed and during the following year there was a slow growth of the tumor into the left proximal femoral region.

The patient was admitted to the Department of Surgery at the Serafimer hospital in September 1964. During the next six months he was treated with cytostatics (methotrexate) through an indwelling catheter in the left iliac artery. This treatment was ineffective. Tumor growth continued and the patient was readmitted to the Orthopedic clinic in March 1965. At that time the tumor occupied part of the pelvis and impaired the bladder function. Since no metastases could be detected in the lungs or elsewhere a left hemipelvectomy was performed as a palliative and

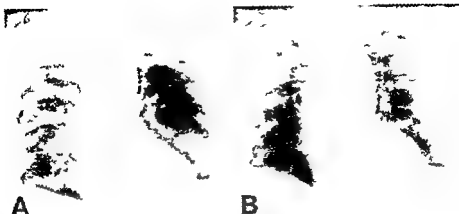


Figure 1 Roentgenologic survey of lungs before (A) and 2 years after (B) introduction of ^{32}S sulfate treatment. Widespread metastases were observed on both occasions but there is no evidence of progress in the disease.

hopefully curative measure in April 1955. The operation was considered radical as judged by macroscopic and microscopic examination of the tissues removed. The postoperative course was uncomplicated and training with a prosthesis was started.

In November 1955 pulmonary roentgenograms showed (Figure 1 A) the presence of a large number of small areas of increased density bilaterally which were considered to be chondrosarcoma metastases. Attempts to obtain needle biopsies for histologic confirmation of this diagnosis were unsuccessful.

Soon thereafter treatment with high doses of radioactive sulfate was started at the metabolic ward of the Medical clinic at the Serafiner hospital. The total amount of radioactivity given was 1730 C, in seven separate doses, some of which were given intravenously and others intra arterially as shown in Table 1.

After the first four injections the patient started to feel pain in the distal part of the right tibia. A roentgenogram of this region showed destruction of the bone and the presence of a bone metastasis was suspected (Figure 2 A). Surgical exploration in January 1956 revealed a subcutaneous bluish gelatinous like lobated tumor destroying the cortical layer of the tibia and growing into the marrow cavity. Macroscopically the tumor had the appearance of a chondrosarcoma; the diagnosis was confirmed by microscopic examination. In order to achieve the highest possible concentration of radioactive sulfate in the tibial tumor the next dose was given intra arterially into the right popliteal artery. After two additional intravenous doses of radioactivity the isotope treatment was concluded in July 1956.

During the spring of 1956 the pains in the right tibia disappeared slowly and the patient was again able to stand on his leg and to resume training with the prosthesis. At the end of November 1956 about 10 months after the bone biopsy roentgenograms of the chondrosarcomatous region in the tibia showed no increase in the size of the tumor. On the contrary a marked demarcation and sclerosis of

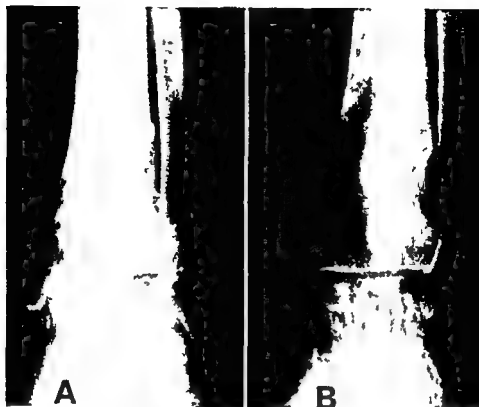


Figure 2 Tibial metastases of chondrosarcoma in January 1966 (A) and 10 months after introduction of ^{90}Sr sulfate therapy (B) On the former occasion diffuse bone destruction and cortical fragmentation were observed whereas after treatment there was marked sclerosis with a sharp border between the lesion and the surrounding bone and soft tissue

the metastasis was observed (Figure 2 B). A second surgical exploration of this region was made in November 1966. No extraskeletal tumor tissues were then seen macroscopically. A dense fibrotic scar tissue was found in the muscles and the cortical layer of the tibia was hard and sclerotic. No tumor tissue was observed in the cortical or cancellous bone. The absence of viable tumor cells in the extensive biopsy material, was confirmed by a detailed microscopic investigation. The last available roentgenogram of the tibia taken in October 1967 showed no signs of recurrence of the malignant process. With regard to the pulmonary metastases frequent roentgenologic surveys of the lungs from the beginning of the isotopic treatment in November 1965 until October 1967 have failed to show any definite increase in size of the metastases or any other sign of progress in the pulmonary involvement (Figure 1 B).

The patient's general condition which was reasonably good throughout the isotopic treatment has steadily improved during the two last years. Since his discharge from the metabolic ward in March 1966 he has been leading an essentially

Table 1

Injection no	Date	Dose mG	Administered into	Urine collection days
I	29 Nov 1965	250	Superior vena cava	7
II	6 Dec 1965	200	Right bronchial artery	14
III	20 Dec 1965	200	Right bronchial artery	7
IV	27 Dec 1965	200	Cephalic vein	14
V	17 Feb 1966	250	Right popliteal artery	—
VI	17 May 1966	230	Cephalic vein	—
VII	18 July 1966	250	Cephalic vein	—

Date dose and route of administration of the seven injections of ^{32}S sulfate. Duration of urine collection for radio assay is also given — indicates that urine was collected for safe disposal only.

normal but sedentary life in his home except for four short periods in the hospital for treatment or checkups. However the patient recently (Oct. 1967) developed a diabetes mellitus which is well controlled with a small dose of tolbutamide.

EXPERIMENTAL

Isotope Treatment

The isotope used in the treatment was obtained as a carrierfree neutral sterile solution of sodium sulfate ^{32}S from the Radiochemical Centre Amersham England. After carefully controlling the radioactivity of each batch of the isotope the actual dose for administration was diluted to 10 ml with sterile normal saline.¹ The isotope was injected over a period of about five minutes through an indwelling catheter. Table 1 shows the amount of ^{32}S -sulfate given each time the administration routes and the injection days.

Strict precautions were taken in order to reduce the hazards of undue isotopic contamination. Routines normally employed in cases of highly infectious diseases were used in the general management of the patient during the first two months of intensive treatment and subsequently for at least 10 days after each single dose of ^{32}S sulfate. Moreover during the first week after the injection the urine was quantitatively collected by means of an indwelling urethral catheter. The

¹ Mr L. Johansson M A Radiophysical Institute Karolinska Institutet performed the radioactivity controls and the preparation of the different doses to be injected.

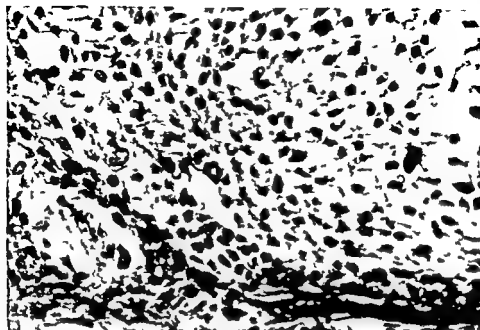


Figure 3 Microscopical section from biopsy of tibial metastasis (cf Figure 2 4) obtained in January 1966 Low-differentiated chondrosarcoma with typical structure containing immature chondroblastic tumor cells ($\times 400$)

catheter was connected to plastic tubing draining into a plastic bottle which was kept in ice in order to prevent bacterial growth and subsequent derangement of sulfate conjugates. The bottles were changed at scheduled times, sealed in the patient's room and transported to a laboratory where facilities for the handling assay and disposal of high doses of radioactivity were available.

Histologic Studies

Material for histologic examination of the chondrosarcomatous lesion was obtained on several occasions. The primary tumor in the tuberosity of the ischium had the appearance of a typical chondrosarcoma. The recurrent pelvic tumor had a very similar appearance, with only very slight regressive changes in spite of the preceding treatment with cytostatics.

The characteristic chondrosarcomatous appearance of the tibial metastasis before treatment with ^{32}S is shown in Figure 3. A section of the same metastasis ten months later was strikingly different (Figure 4). There was marked sclerosis and hyalinization of the tissue. The



Figure 4 Section of the same metastasis 10 months after instituting ^{32}S sulfate treatment (cf Figure 2B) Marked hyalinization and sclerosis of the tumor tissue containing but few tumor cells without signs of viability ($\times 400$)

tumor seemed to be completely devitalized and there were no signs of viability among the few remnant tumor cells

Hematologic Studies

An estimate of the radiation received by the tumor tissue as compared with that received by the bone marrow could not be worked out. Therefore frequent hematologic studies were made during the entire course of treatment to guide the timing of the isotope administration.

Studies on the peripheral blood included determination of the number of erythrocytes, leukocytes and thrombocytes as well as hemoglobin concentration. The results are summarized in Figure 5. In general as illustrated by this figure the hematologic complications were not very serious. On two occasions during the treatment, about one month and six months after its inception, the hemoglobin level dropped to values around 9 g/100 ml. The erythrocyte and thrombocyte counts remained at safe levels with the lowest values one month and four months after initiation of ^{32}S therapy. The leukocyte count

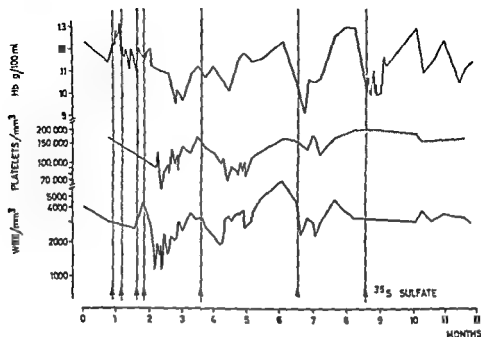


Figure 5 Level of hemoglobin platelets and white blood cells during treatment of the patient. The arrows indicate the times when the isotope was injected.

was somewhat more strongly influenced by the ^{35}S treatment. It fell to 1200 cells/mm³ after six weeks of treatment at which time one curie of radioactivity had been given. Subsequent single doses of the isotope caused only minor reductions in the white cell count.

Frequent samples of bone marrow were taken by sternal puncture during the course of treatment particularly during the first two months when marrow smears were investigated several times weekly. No significant pathological changes were ever noted with respect to erythropoiesis, thrombocytopoiesis, or the appearance of reticular cells. Between the tenth and fortieth day after the beginning of treatment myelopoiesis was found to be hypoplastic with the occurrence of various numbers of damaged cells. This was interpreted as indicating a mild to moderate toxic effect on myelopoiesis. Two months after the beginning of the treatment the bone marrow had normalized. Subsequently no significant pathological changes in the bone marrow were observed. At the last examination (Oct. 1967) all the above mentioned hematologic parameters were normal.

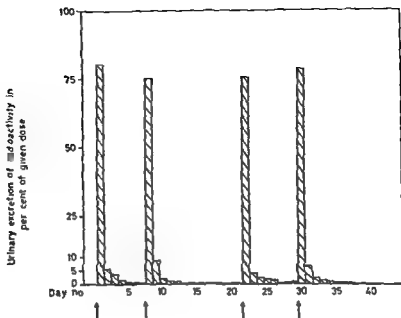


Figure 6 Schematic representation of daily urinary excretion of radioactivity following injections I-IV expressed as per cent of given dose. The arrows indicate the times of isotope injection.

Urinary Radio-Assays

The excretion of the radioisotope into the urine was examined after injections I-IV. The radio assays included determination of total radioactivity and of ester sulfate radioactivity. The ^{32}S activity in the inorganic sulfate fraction was calculated as the difference between total and ester sulfate activity. No attempt was made to examine the occurrence of ^{32}S as neutral sulfur since previous studies have shown the excretion in this fraction to be negligible (see page 12). Total ^{32}S activity was measured at infinite thinness with a Geiger Müller counter equipped with a thin endwindow tube. Aliquots of 100 μl of properly diluted (up to 10 000 times) samples of urine were applied to frosted aluminum plates and dried at 80-90 $^{\circ}\text{C}$. As a reference 100 μl aliquots of a dilution of the isotope solution given to the patient were always used.

The following method was applied for determination of ester sulfate ^{32}S . The ester sulfate fraction was separated from inorganic sulfate by precipitation of the latter as BaSO_4 . After centrifugation the supernatant was filtered through Munktell filter paper no. 00H. The excess

Table 2

Collection period	Fraction	Injection no			
		I	II	III	IV
Whole period	Inorganic sulfate	79.2	71.2	67.1	81.6
	Ester sulfate	13.2	18.6	19.5	10.3
	Total	92.4	89.8	86.6	91.9
First 24 hours	Inorganic sulfate	69.6	58.9	57.7	70.0
	Ester sulfate	10.7	16.0	17.8	8.5
	Total	80.3	74.9	75.5	78.5
Second 24 hours	Inorganic sulfate	4.6	7.3	3.2	5.8
	Ester sulfate	0.8	1.4	0.7	0.7
	Total	5.4	8.7	3.9	6.5
Third 24 hours	Inorganic sulfate	2.8	1.5	2.1	2.2
	Ester sulfate	0.9	0.4	0.4	0.2
	Total	3.7	1.9	2.5	2.4

Urinary recovery of ^{35}S activity in per cent of administered dose after the first four injections

of barium ions was precipitated as BaCO_3 by bubbling CO_2 through the solution. Centrifugation and filtration rendered a clear solution aliquots of which were plated for radioassay as described above.

As shown in Figure 6 and Table 2 approximately 90 per cent of the administered radioactivity was recovered in the patient's urine. Most of

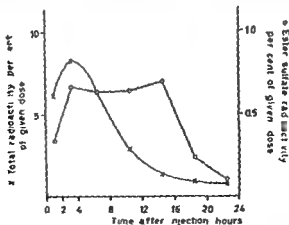


Figure 7. Excretion rate of total and of ester sulfate radioactivity during the first 24 hours after injection I. The excretion rates are expressed in per cent of the given dose excreted per hour.

this radioactivity was recovered during the first 24 hours and occurred in the inorganic sulfate fraction. However, as shown in Table 2, 10 to 20 per cent of the dose was excreted in the form of ester sulfates. This fraction was somewhat higher after doses II and III injected into the bronchial artery than after doses I and IV which were administered intravenously. An analysis of urinary radioactivity on an hourly basis was performed during the first 24 hours of collection following injection I. The excretion of total radioactivity, mainly representing inorganic sulfate, was highest during the first few hours with a peak at about 4 hours after injection (Figure 7). Radioactivity in the ester sulfate fraction, on the other hand, showed a more delayed excretion pattern, presumably reflecting the appearance in the urine of different ester sulfates formed and excreted at different rates.

DISCUSSION

The diagnosis of pelvic chondrosarcoma in the present case is well founded. It is based on the typical symptoms, the course of the disease, and the characteristic roentgenographic and morphologic findings. The same applies to the tibial metastasis, the nature of which was also confirmed by microscopy. With regard to the pulmonary lesions, microscopic characterization of the suggested chondrosarcomatous structure is still lacking due to the obvious difficulty in obtaining representative biopsy material.

The clinical course was strikingly changed in a favorable direction after initiation of ^{35}S therapy. The patient's general condition improved considerably. The tibial metastasis apparently was completely devitalized; there was no further progress of the pulmonary involvement, and there have been no signs of the appearance of new metastases. To our knowledge, such a therapeutic effect has not been demonstrated previously with ^{35}S treatment or cytostatic drugs. The question then arises to what extent the advantageous course of the disease during the last two years can be credited to the ^{35}S therapy.

It must be pointed out that some types of chondrosarcomas grow very slowly, and that generalized metastases usually appear late in the course of the disease. Neither can the possibility of a spontaneous regression of the metastases during the period of observation be completely excluded. However, in view of the recurrence and rapid growth of the primary tumor, the failure of cytostatic treatment, and the rapid

appearance of pulmonary metastases after hemipelvectomy it seems unlikely that the change in course was spontaneous. We assume therefore that the cessation of growth of the pulmonary metastases and the devitalization of the tibial metastasis was in fact a result of the ^{32}S treatment. The more favorable effect of this therapy than in previously reported cases may in part be due to a greater radiosensitivity of the tumor or to an earlier institution of treatment. However in our opinion the most important factor was probably that the patient received the highest total dose of ^{32}S sulfate thus far reported in the literature.

In spite of the higher dose of ^{32}S sulfate in the present case the bone marrow was only slightly affected in comparison to previous cases (Gottschalk *et al* 1959 and b Andrews *et al* 1960 Bolstein & Marcus 1963). Nor were there any signs of damage to other tissues or any symptoms of a generalized radiation sickness. On the contrary the patient's general condition has been good ever since the treatment was completed. Whether his recently discovered diabetes has been precipitated by radiation injury of the beta cells of the pancreas or is only coincidental can not be established. However it seems unlikely that such a radiation injury would not become manifest until two years after the institution of ^{32}S therapy. Nevertheless animal experiments have shown that ^{32}S sulfate is taken up by the pancreatic islets. This uptake occurs mainly in the vascular connective tissue strands and only to a limited extent in the specific cells (Odeblad & Boström 1952 Vorhagen & Odeblad 1955 Diderholm & Hellman 1957).

The urinary radio assays performed in the present case gave results that are in agreement with those of previous studies in animals (Laidlaw & Young 1948 Dzierżatkowski 1949 and b Boström *et al* 1963) and in human (Gottschalk *et al* 1959 and b Andrews *et al* 1960 Bolstein & Marcus 1963). The bulk of an administered dose of ^{32}S sulfate is swiftly excreted into the urine mainly as inorganic sulfate but to some extent also as ester sulfate. It should be of interest in further therapeutic trials with ^{32}S sulfate to subject the urinary excretion of ^{32}S labeled ester sulfates to a closer analysis *eg* in order to elucidate the possible relationship between the mode of administration of the isotope and excretion of ^{32}S labeled ester sulfates.

The experience gained from this case indicates that it is possible to administer high doses of ^{32}S sulfate without untoward effects through the use of multiple doses. Conceivably a considerably higher total dose of ^{32}S sulfate could have been tolerated by the patient and might be utilized in future cases. A proposed therapeutic scheme could be work

ly single doses of about 250 mC four times bi monthly until from two to three curies or possibly more had been administered. In the execution of such a scheme attention should be given to the hematological response. Whenever possible arterial injection or perfusion should be employed rather than intravenous administration. Furthermore since the greater portion of a therapeutic dose is eliminated in the urine measures should be taken to reduce undesirable irradiation of the urinary passages particularly the bladder and to ensure complete recovery and safe disposal of the isotope. A high urinary output volume should be maintained. The use of an indwelling urethral catheter preferably with continuous lavage is also advisable.

The possibility of combining ^{32}S treatment with other methods known to depress the synthesis of mesenchymal tissue constituents either by drugs (Bostrom *et al* 1964) or roentgenologic treatment (Andrews & Holland 1966) must be further explored. It is our opinion that particular attention should be paid to the appropriate timing of such auxiliary measures in relation to the course of ^{32}S sulfate treatment. The value of ^{32}S sulfate in the treatment of chondrosarcoma cannot as yet be considered as fully established. In our opinion however the present promising observations are a stimulus to further attempts to utilize this radioisotope in the search for an effective non surgical treatment of this malignancy.

SUMMARY

A case of chondrosarcoma with pulmonary and skeletal metastases occurring after hemipelvectomy is described in which treatment with ^{32}S -sulfate was successfully applied.

The total dose was 1 735 C and is the highest thus far reported. The isotope was given in seven separate injections by various intra arterial and intravenous routes during a period of seven months.

The patient's general condition improved markedly with the institution of ^{32}S therapy. For the last two years he has been leading an essentially normal but sedentary life. There has been no increase in the size of the pulmonary metastases. Moreover devitalization of the tibial metastasis was obtained as verified histologically.

The treatment did not cause any serious damage to the bone marrow. Nor were there any signs of damage to other tissues or any symptoms of a generalized radiation sickness. Hence a therapeutic scheme involv-

ing even higher doses is suggested for future attempts to utilize ^{32}S sulfate in the treatment of chondrosarcoma

RESUME

On décrit un cas de chondrosarcome avec métastases pulmonaires et osseuses après hémipelvectomy pour lequel un traitement par sulfate de ^{32}S a été appliqué avec succès

La dose totale a été de 1 730 C et est la plus haute rapportée jusqu'à présent L'isotope a été administré en 7 injections séparées par diverses voies intrartérielles et intraveineuses pendant une période de 7 mois

L'état général du patient s'est amélioré de façon notable avec ce traitement

Au cours des deux dernières années il a mené une vie essentiellement normale mais sédentaire

Il n'y a pas eu d'accroissement dans la dimension des métastases pulmonaires

De plus il a été vérifié histologiquement qu'une dévitalisation des métastases du tibia a été obtenue Le traitement n'a causé aucun dommage sérieux et moelle osseuse

Il n'y a pas eu non plus de signes de dommages à d'autres tissus ainsi que de symptômes de maladie consécutive à une irradiation généralisée

Ainsi une thérapie incluant des doses encore plus fortes est suggérée dans les tentatives futures d'utilisation du sulfate dans le traitement de la chondrosarcome

ZUSAMMENFASSUNG

Eine erfolgreiche Behandlung von pulmonalen und Skelett Metastasen von Chondrosarcom mit ^{32}S Sulfat nach Hemipelvectomy wird mitgeteilt

Die totale Dosis war 1 730 C und stellt die höchste bisher publizierte Dosis dar Die Isotope wurde in 7 separaten Injektionen teils intravenöse teils intrarterielle im Laufe von 7 Monaten verabreicht

Der Allgemeinzustand des Patienten verbesserte sich während der Behandlung mit ^{32}S Sulfat deutlich In den letzten beiden Jahren lebte er nahezu normal jedoch mit begrenzter Aktivität Es wurde keine Vergrößerung der Lungen metastasen beobachtet Ausserdem konnte eine Devitalisierung einer Tibiametastase histologisch nachgewiesen werden

Die Behandlung hatte keine Schäden des Knochenmarkes zur Folge

Auch traten keine Zeichen von Gewebsschädigung oder generelle Strahlenschäden in Erscheinung

Auf Grund dessen beabsichtigt man die Dosierung von ^{32}S Sulfat bei zukünftiger Behandlung von Chondrosarcom zu erhöhen

REFERENCES

- Andrews J R., Swarm R. L., Schlachter L., Brace K. C., Rubin Ph., Pergental D. M., Gump H., Siegel H. & Swain R. W. (1960) The effects of one curie of sulfur 35 administered intravenously as sulfate to a man with advanced chondrosarcoma *Amer J Roentgenol* 83 123-134
- Andrews J R. & Holland D. (1965) Sulfur 35 studies in human chondrosarcoma *Am J Roentgenol* 94 798-806
- Bostrom H. (1959) On the metabolism of the sulfate group of chondroitinsulfuric acid. *J Biol Chem.* 196 477-481
- Bostrom H. & Vestermark A. (1959) Studies on ester sulphates 4 Ester sulphate patterns in the urine of different species. *Acta Soc Med Upsalien* III 194-203
- Bostrom H., Gustavsson H. E. & Wengle H. (1963) Studies on ester sulphates 18 Ester sulphate formation in the germfree rat. *Proc Soc Exp Biol Med* 114 742-747
- Bostrom H., Berntsen K. & Whitehouse M. W. (1964) Studies on ester sulphates 20 Biochemical properties of antiinflammatory drugs II Some effects on sulphate- ^{35}S metabolism *in vivo* *Biochem Pharmacol* 13 413-420
- Bostrom H. & Rolén L. (1965) Metabolism of glycosaminoglycans in "The Amino Sugars" Vol II B. E. Balazs and H. W. Jeanloz eds. Academic Press New York, p 45-80
- Bostrom H., Friberg U., Larsson, K. S. & Nilsson U. (1965) On the *in vitro* incorporation of ^{35}S sulfate in chondrosarcomatous tissues *Acta orthop scand* (in print)
- Botstein C. & Marcus V. (1963) A case of recurrent chondrosarcoma of the maxilla treated unsuccessfully with sulphur 35 *Amer J Roentgenol* 89 555-558
- Diderholm H. & Hellman B. (1957) An autoradiographic study of the uptake of labelled sulphate in the pancreatic tissue of the mouse *Acta Soc Med Upsal* 62 23-8
- Dziewiatkowski H. D. (1949 a) Rate of excretion of radioactive sulphur and its concentration in some tissues of the rat after intraperitoneal administration of labelled sodium sulfate *J Biol Chem* 178 197-209
- Dziewiatkowski H. D. (1949 b) On the utilization of exogenous sulfate sulfur by the rat in the formation of ethereal sulfates as indicated by the use of sodium sulfate labeled with radioactive sulfur *J Biol Chem* 178 339-393
- Gottschalk, R. G., Alpert L. K. & Alpert H. E. (1959 a) The use of large amounts of radioactive sulfur in patients with advanced chondrosarcomas I Clinical and hematologic observations *Cancer Res* 19 1070-1077
- Gottschalk, R. G., Alpert L. K. & Miller F. O. (1959 b) The use of large amounts of radioactive sulfur in patients with advanced chondrosarcomas II Distribution and tissue irradiation *Cancer Res* 19 1018-1025

- Laidlaw J C. & Young L. (1948) Studies on the synthesis of ethereal sulfates *in vivo* *Biochem J* 42 (Proc.)
- Norhagen A. & Odeblad E. (1955) Uptake of radiosulfate in the islets of Langerhans of mice *Arch Biochem Biophys* 54 562-563
- Odeblad E. & Boström H. (1952) An autoradiographic study of the incorporation of S^{35} labeled sodium sulfate in different organs of adult rats and rabbits. *Acta path et microbiol scandinav* 31 339-344
- Thomas L. (1956) Reversible collapse of rabbit ears after intravenous papain and prevention of recovery by cortisone *J exp Med* 104 339-344

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CONTRACTURE OF THE QUADRICEPS MUSCLE IN CHILDREN

A Report of 12 Cases

By

ROLF HAGEN

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The purpose of this paper is to emphasize that an important factor concerning the etiology of quadriceps contracture in children is the administration of intramuscular antibiotic injections into the thighs. A total of twelve patients with a flexion deficit in one or both knee joints have been treated during the last four years. All the children suffered from severe illnesses soon after birth and received large injections of antibiotics into the thighs. Three cases in our material presented several characteristic signs of this disorder and are described here.

CASE REPORTS

Case 1 A girl aged one year and six months was born four weeks before term. At the age of three weeks she suffered from sepsis originating from the urinary tract and complicated by staphylococcal pneumonia. She received 40 million units of crystalline penicillin into both thighs within a period of six weeks (Figure 1). Two years after the quadriceps-plasty gait and squatting were normal and there was no reduction in strength of the quadriceps muscle (Figure 2). This child is in fact, completely restored.

Case 2 A boy aged five years had a congenital ventricular septal defect and was given 130 million units of penicillin because of endocarditis at five months of age. A flexion deficit developed in both knees and the condition progressed for two years despite of intense physiotherapy (Figures 3-5). Characteristically during an active or passive attempt to force the flexion the movement was stopped suddenly and exactly at one point as if some mechanical obstacles were in the way. The decreased range of flexion was not accompanied by pain and even vigorous efforts to force the hindrance were painless. Two years after a bilateral quadriceps plasty



Figure 1

Case 1 Figure 1 Several white puncture marks are shown anterolaterally on the left thigh. Similar marks of injections were present on the other thigh. Figure 2 40° of flexion before operation. Normal range of movement after operation.

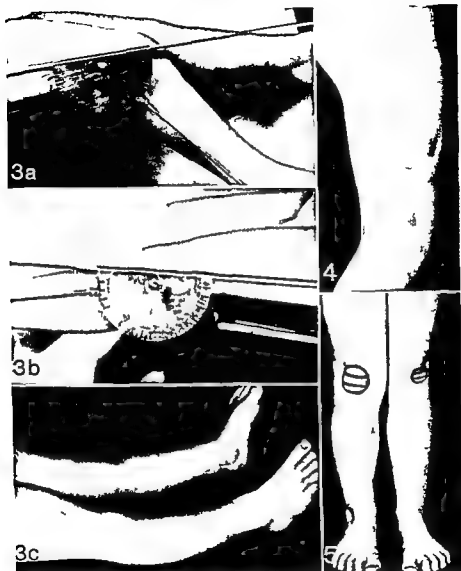


Figure 2

the gait had improved considerably and he presented a nearly normal squatting ability (Figure 6).

Operation Technique

Figure 7 gives a schematic drawing of the operative procedure. The quadriceps muscle was explored through an anterolateral incision. The operation consisted of a lengthening of the rectus femoris tendon and iliotibial tract and a simple division of the vastus intermedius tendon and all tight adhesions. There was considerable fibrosis in the depth of the subcutaneous tissue; the fascia lata was fibrotic and tight; it was 4–5 mm thick and was adherent to the underlying muscle. The vastus lateralis, medialis and intermedius were dissected free from the rectus femoris. All four heads of the quadriceps muscle were fibrotic and contracted with massive adhesions to the intermuscular fasciae. A Z lengthening of 5 cm of the rectus femoris resulted in some improvement, but the further restriction of flexion was caused by tightness of



Figures 3-5

Case 9 Figure 3 Preoperatively 50° of flexion of right knee joint 10° of flexion of the left and 15° of hyperextension on both sides Figure 4 The quadriceps tendon tightened by maximal flexion and the dimples were more visible Figure 5 Left patella hypoplastic and situated higher and more laterally than right

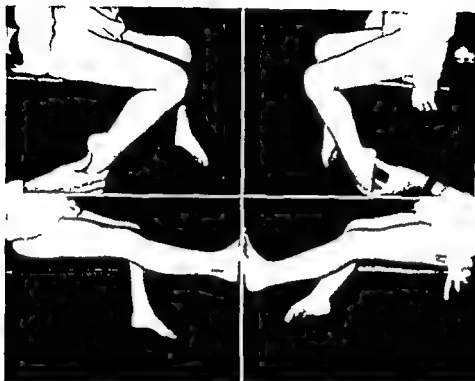


Figure 6

Case 2 Figure 6 Two years after operation knee flexion 10-130° on right side 20-90° on left and passive extension to 0 position on both sides

the vastus intermedius tendon which was divided transversely. However full flexion was not possible until the distal tibial tract was lengthened by an oblique incision upward and backward and the insertions of the vastus medialis and lateralis into the central tendon were divided. These muscles were sutured to the tendon again while the knee was held in 90° of flexion and a toe to groin cast immobilisation was continued for 2 weeks.

Histological Examination

There are considerable degenerative changes in the striated muscle fibres in sections from all parts of the left quadriceps muscle (Figures 8-10). The muscle bundles are partly replaced by fibrous tissue and partly by adipose tissue. There is some haemorrhage in the tissue and infiltration with lymphocytes, plasma cells and a few granulocytes. Conclusively the histological picture is characteristic of muscle tissue

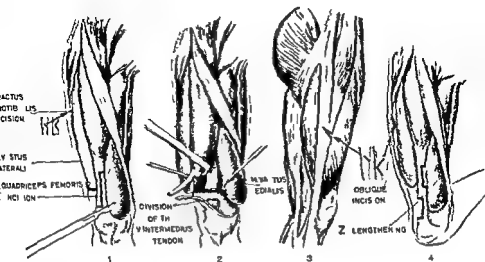


Figure 7

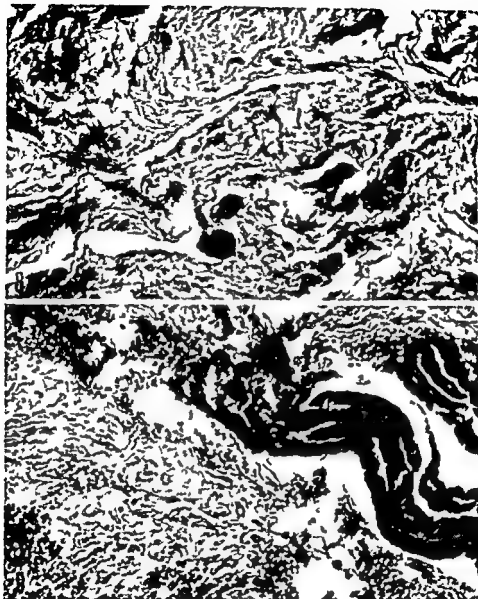
with degenerative changes (Rikshospitalet the Institute of General and Experimental Pathology prof Olav Hulmar Iversen)

Case 11 A boy aged 6 years was born six weeks before term and received 14 million units of penicillin from the first day of life because of bronchopneumonia complicated by sepsis. The correct diagnosis was established at the age of five years (Figure 11). A modified Smith-Petersen incision was employed bilaterally in this case. Considerable amounts of fibrotic tissue were removed and the rectus tendon lengthened 4 cm at its origin. Postoperatively the patient was put in bed in the prone position with sand bags on the buttocks and with the knees flexed 90°. He was out of bed on the 34th postoperative day (Figure 12).

MATERIAL

Table 1 gives details of our twelve patients with quadriceps contracture. The material consists of 8 boys and 4 girls. There were 1 rightsided, 3 leftsided and 8 bilateral contractures. Fifty per cent of the children had been born two to eight weeks before term.

Usually the antibiotics had been given because of infections but also as a prophylactic measure especially in connection with prematurity (case 5 and 7) and operation (case 9). Crystalline penicillin had been given in doses from 8 to 130 million units within a period of 3 to 9 weeks. Most of the prematures had received injections from the first day of life, case 2 from the age of five months and the remaining were three to four weeks old. Two conservatively treated cases (case 6 and 7) had received antibiotics in small doses. All our patients showed evidence of previous thigh injections i.e. puncture marks and dimples.



Figures 8 9

Case 2 Figure 8 Photomicrograph of section of rectus femoris shows that the tissue is replaced by a collagenous and fibrous tissue with comparatively few cells only few preserved muscle bundles Figure 9 Section of vastus medialis shows muscle bundles ending abruptly at a collagenous and fibrous tissue

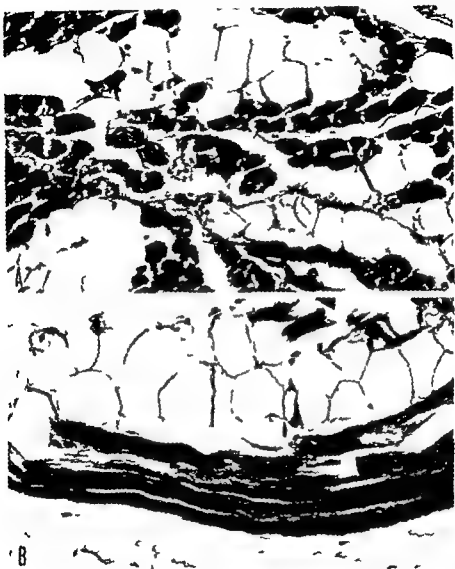


Figure 10 Vastus intermedius (A) and vastus lateralis (B)
Individual muscle bundles are partly replaced by adipose tissue

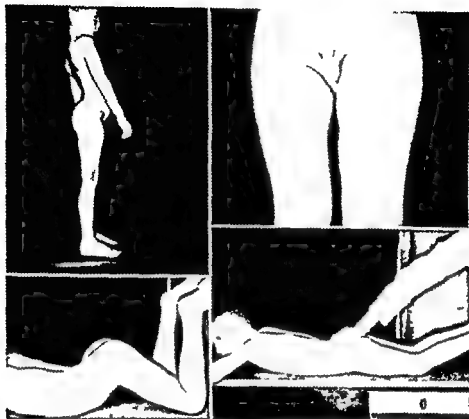


Figure 11

Case 11 Figure 11 Increased lumbar lordosis clearly shown in the prone position with the knee 90° flexed. Dimple visible proximally on right thigh. With normal lordosis and 0° position in the hip joints only 30° of flexion of the knees.

All together 14 operations were performed upon 10 patients, and 4 children had bilateral operations. A flexion of at least 90° is no indication for operative treatment because a knee flexion up to this limit is sufficient for all important movements; these cases however are followed up at the out patient department.

Table II shows the anatomical distribution of fibrosis in 12 operations on 9 patients. The operative procedure in these cases was usually the same as that described in connection with case 2.

RESULTS

Comparison of the pre- and postoperative range of knee movement (Table I) shows that all cases obtained at least 90° flexion. The range of flexion was usually recorded in the prone patient with 0° position in the hip joints. This position may present a lesser degree of flexion

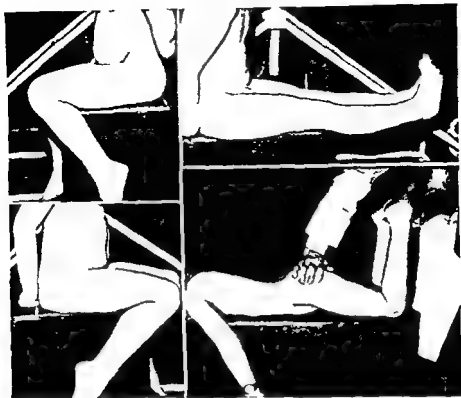


Figure 19

Case 11 Figure 19 One year postoperatively flexion to 130° in sitting position and extension with normal power to 0° in prone position flexion to 90°

compared with the sitting position especially if the fibrotic changes and contracture are confined mainly to the rectus femoris. Concerning the postoperative active extension the object was to obtain 0° position by physiotherapy and what is probably more important by stimulating the children as much as possible to daily activity and play. Among the patients with a postoperative observation time of 2 years the active extension defect was sometimes 10-20° while there was a little more deficiency of extension among those operated upon during the first 1½ year. All these patients have passive extension to 0° position but no hyperextension. The power of the quadriceps muscle continued to improve during the observation period in all the children. The quadriceps plasty was modified a little in two cases (case 5 and 8) in order to obtain a stronger extensor mechanism postoperatively. The Z

Table 1 Details of twelve patients with quadriceps contracture

Case number	S	Sex	Age last seen (months)	Femoral lesion	Findings at Biopsy	Findings at necropsy (lungs and kidneys)	Degree of joint contracture post-operative		Age at operation	Operation		Time after operation	Degree of joint contracture last seen (months)		
							R	L		R	L		R	L	
1	F	L	5 mos		Staphylococcal pneumonia		normal	0	12	16 mos		2 yrs	normal	0	100
2	M	R+L	5 mos		Pneumonia (upper lobe) Subtotal atelectasis		0	90	0	10	6 yrs		2 yrs	10	120
3	F	L	5 mos		Sepsis		normal	0	90	8 yr		2 yrs	normal	22	90
4	M	R+L	12 mos		Staphylococcal pneumonia Pyogenic abscess		0	120	0	40	5 yrs		2 yrs	0	120
5	M	R+L	12 mos		Pneumonia abscess		0	90	0	20	6 yrs		2 yrs	0	90
6	M	R+L	2 yrs		Pneumonia		0	90	0	90					
7	M	R	5 yrs		Acute inflammation of the knee joint		0	90	normal						
8	M	L	2 yr		Acute inflammation of the knee joint		normal	0	40	2 yrs		10 mos	normal	0	12
9	F	R+L	5 mos		Emphysema (upper lobe) (upper lobe)		0	20	0	10	4 yrs		10 mos	20	100
10	M	R+L	3 yrs		Emphysema (upper lobe) Sepsis		0	20	0	22	4 yr		10 mos	20	90
	M	R+L	5 yrs		Emphysema (upper lobe) Sepsis		0	20	0	30	6 yrs		12 mos	0	90
2	F	R+L	6 yr		Sepsis		0	100	0	20	6 yrs		7 mos	0	100

Table 2 Anatomical distribution of fibrosis in muscle operations on nine patients with quadriceps contracture

MUSCLE AFFECTED	NUMBER OF CASES
VASTUS LATERALIS MEDIALIS INTERMEDIUS AND RECTUS FEMORIS	7
VASTUS LATERALIS INTERMEDIUS AND RECTUS FEMORIS	4
VASTUS LATERALIS AND RECTUS FEMORIS	1

lengthening was performed on the combined tendons of the rectus and vastus intermedius. This is perhaps not a sound principle because the rectus is a two-joint muscle and the intermedius a one joint muscle. Nevertheless it did not seem to be of any practical significance and at the follow up these two children presented active extension to 0° position.

Preoperatively the younger children had a tendency to keep the lower extremity extended when crawling and were not able to squat while the older children had a peculiar gait and way of running. The lower extremity was put forward simultaneously with abduction out ward rotation and flexion movement in the hip joint. Most of the pa-

tients walked with the knee joints nearly extended even though some flexion was still possible. They also tended to walk with the legs more or less wide apart especially when walking up hill or upstairs.

Locomotion was much better after the operation not only for unilateral but also for bilateral contracture. The abduction and outward rotation movements disappeared completely. The knee stability seemed to be satisfactory because the hamstrings support the extensor muscles in this respect.

ETIOLOGY

Similar reports on quadriceps contracture in children have been published in the last 6 years and it appears that *J. V. Todd* (11) was the first to mention this subject and to warn against injections.

Sleen Johnsen (10) has reported one case in a paper on intramuscular injections and recommended treatment with exercises because the flexion deficit was moderate in his patient.

Hnevkovsky (6) published 12 cases and has later collected a total of 17 cases (*Lloyd Roberts & Thomas* 1964). But he was able to establish a definite history of injections into the thigh in only 4 of them. He emphasized that there may be two syndromes: the progressive idiopathic type due to a congenital muscular dysplasia of rectus and intermedius and the type due to injections.

Fairbank & Barrett (1) described identical girl twins with flexion deficits in both knee joints. They assumed a genetic origin and thought the contracture to have most in common with congenital torticollis. In 1964 however *Lloyd Roberts & Thomas* reported that the twins had been given intramuscular antibiotics for a month because of prematurity but the exact site of these injections is not known. Their own material of 3 patients had all received injections into the thighs (8).

Gammie Taylor & Ulrich (2) suggested that the condition might be due to a congenital muscle contracture related to that occurring in club foot or Sprengel's shoulder.

Gunn (3) reported 22 cases from Singapore 15 of which were due to injections. At the same time *Karlen* published 6 cases also from Singapore. He was in agreement with *Hnevkovsky* and used the term congenital fibrosis of the vastus intermedius for his cases.

Lastly *Saunders Hoefnagel & Staples* (9) presented one case with a unilateral contracture due to injections.

DISCUSSION

The appearance of these contractures during the last 10 years may be related to the increasing frequency of antibiotic injections into the quadriceps muscle. However detailed clinical histories are not always given. It is therefore not known how many children in these materials were premature or had illnesses that might have required intramuscular injections. Six cases in our material presented illustrative diagnostic problems and the evidence of previous injections could be very difficult to observe and was indeed overlooked by several physicians. Case 1 was interpreted as either arthrogryposis or a rare neurologic disease. Case 3 was first thought to be due to trauma then to inflammation and thirdly to a discoid meniscus and in addition a postpoliomyelitic paresis due to the atrophy shortening of the inferior extremity and an absent patellar reflex. Case 4 and 5 were erroneously diagnosed as being snapping hip and Child Legg Perthes disease. Lastly in case 6 the gut led to the diagnosis of cerebral palsy and it appeared to be difficult to demonstrate the clinical history because the child had been adopted in early infancy and the puncture marks could only be seen under a magnifying glass.

Summarizing the analysis of our material and similar reported cases seem to indicate that most of these contractures are due to injections but still a few cases may be of a congenital origin.

Concerning the pathogenesis in our cases the most reasonable explanation seems to be that the injections induce considerable oedema and haemorrhage and even necrosis in the muscle with the subsequent development of fibrosis adhesions and contractures. It is very likely that the injected amount of antibiotic is too large in relationship to the volume of the muscle and in this way separates the muscle bundles and fibres. Another important factor may be that the blood flow of the muscle is dependent upon the activity of the latter and probably only a minor portion of the capillaries are active in these quietly lying severely ill newborn children. Consequently the resorption continues during a much longer period of time and the quadriceps muscle is saturated with the injected antibiotic solution (4). Nurses who attended some of these children were often astonished by the swelling of the thigh following these large and repeated injections and for several weeks case 2 presented even a necrosis in the left thigh. Harrold (5) has described a similar pathologic condition of rigid valgus foot from

fibrous contracture of the peronei probably due to pressure from a splint leading to muscle ischemia and death

Most of our patients received smaller doses of streptomycin and chloromycetin in addition to penicillin. However, it is supposed to be of less importance what kind of antibiotic is injected even if a difference in their tissue damaging effect could be due to various properties of the solutions, i.e. an unphysiological pH, hypertonicity or a direct myotoxic effect (4). The severity of the symptoms is dependent upon the amount of antibiotics injected, the duration of the treatment and the interval between such treatment and surgical intervention.

The pediatricians play an important role regarding prophylactic measures of this disorder (4). It is very important to keep children with a history of previous injections under observation in order to obtain an early diagnosis of progressive flexion deficits. From the example of our first patient it appears that the prognosis seems to be very good if the condition is recognized in early infancy.

SUMMARY

A material of twelve cases of quadriceps contracture in children is analysed with special reference to the clinical and microscopical pictures. All the children had severe illnesses soon after birth and received large injections of antibiotics into the thighs. It is assumed that the injections induce oedema, haemorrhage and even necrosis in the quadriceps muscle with the later development of fibrosis and contracture.

Lengthening of the rectus femoris and the iliotibial tract and division of the vastus intermedius tendon and all tight adhesions proved to be successful and restored good function.

RESUME

Un matériel d'observation de 12 cas de contracture du quadriceps chez des enfants est analysé et il est donné une description du tableau clinique et microscopique. Tous les enfants avaient souffert de maladies graves peu de temps après la naissance et avaient reçu des injections d'antibiotiques dans la cuisse. Il est supposé que les injections ont provoqué de l'œdème, des hémorragies et peut être même des nécroses dans le muscle quadriceps avec plus tard la formation de fibrose et de contracture.

La longueur du droit antérieur femoral et de la région iliotibiale

ainsi que la division du tendon vaste interne et toutes les insertions de la cuisse semblent être excellentes avec une bonne restauration fonctionnelle

ZUSAMMENFASSUNG

Ein Material von zwölf Fällen von kindlichen Quadricepskontrakturen mit besonderer Beschreibung des klinischen und histologischen Bildes wird analysiert. Alle Kinder litten an schweren Erkrankungen kurz nach der Geburt und erhielten grosse Injektionen von Antibiotica in die Oberschenkel. Man nimmt an, dass die Injektionen Ödem, Blutungen und sogar Nekrosen im Quadricepsmuskel hervorriefen, die später zur Entwicklung von Fibrose und Kontraktur führten. Verlängerung des Rectus femoris und Tractus ileotibialis sowie Über-schneidung der Sehne des Vastus intermedius und aller straffen Verwachsungen erwiesen sich als erfolgreich und stellten eine gute Funktion wieder her.

REFERENCES

1. Fairbank T J & Barrett A M (1961) Vastus intermedius contracture in early childhood. Case report in identical twins. *J Bone Jt Surg* 43 B 376
2. Cammie W F P, Taylor J H & Leich H (1963) Contracture of the vastus intermedius in children. *J Bone Jt Surg* 45 B 370
3. Cunn D R (1964) Contracture of the quadriceps muscle. A discussion on the etiology and relationship to recurrent dislocation of the patella. *J Bone Jt Surg* 46 B 492
4. Hagen R (1955) Quadricepskontraktur hos barn. *Tidsskrift for norsk Lægeforening* 117 1476
5. Harrold A J (1965) Rigid valgus foot from fibrous contracture of the peronei. *J Bone Jt Surg* 47 B 743
6. Hnekvosky H (1961) Progressive fibrosis of the vastus intermedius muscle in children. *J Bone Jt Surg* 43 B 318
7. Harlé A (1964) Congenital fibrosis of the vastus intermedius muscle. *J Bone Jt Surg* 46 B 488
8. Lloyd Roberts C C & Thomas T C (1964) The etiology of quadriceps contracture in children. *J Bone Jt Surg* 46 B 498
9. Saunders F P, Hoefnagel D & Staples O S (1965) Progressive fibrosis of the quadriceps muscles. *J Bone Jt Surg* 47 A 380
10. Steen-Johnsen J (1962) Intramuskulære injeksjoner hos barn. *Tidsskrift for norsk Lægeforening* 115-116 895
11. Todd J V (1961) Intramuscular injections. *Brit Med J* (11) 1362

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MUSCLE RECOVERY IN POLIOMYELITIS

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completely or partly paralysed muscles power during the first years after surgery has been performed by Lovett (1955) Sharrard (1955) and others up through 5½ years of patients examined primarily in the Hospital of Physical Medicine and in the Orthopaedic Hospital and Funen

examined by the National Health Service of 3134 paralytic cases 2060 in the epidemic Out of these 3134 patients 1072 in Jutland or Funen In this area remaining 1032 paralytic cases 508 in the named hospitals Out of these 508 patients 155 were over 15 years under 4 years The age distribution of patients in the whole of Denmark and 70 per cent children under 15

the recovery as reliable as possible of 508 These were partly patients examined within 3 months of the onset of paralysis over 4 years of age The group of 240 children in the age range 1-15

of these 240 cases by regular tests were based upon 6 tests done

(1)	an average of 6 weeks	after the onset of poliomyelitis		
(2)	"	"	3 months	"
(3)	"	"	6 months	"
(4)	"	"	1 year	"
(5)	"	"	2 years	"
(6)	"	"	5½ years	"

The evaluation was done by manual testing of the power of each individual muscle in a systematic test of the most important muscles. All the tests were performed by the same two examiners (N B and E T). In assessing muscle power the grading suggested by *Lovett* was used.

0 = No contraction

1 = Trace of contraction

2 = Active movement with gravity eliminated

3 = Active movement against gravity

4 = Active movement against gravity and some resistance

5 = Normal power

Muscles having grade 3 power or over were listed as muscles of functional value.

At the first test done on average of 6 weeks after the onset of polio the following results were recorded:

919 grade 0 muscles		
1483	"	1
1643	"	2
2079	3	"
7006	4	"
<hr/>		
Total	8080 muscles	

If the improvement in muscle power during the 5½ years of the follow up is taken to be 100, about 50 per cent of the improvement occurred within the first 6 months after the onset of polio, about 75 per cent within the first year and 90-95 per cent within the first 2 years. The findings for grade 0 muscles were somewhat different, the improvement in these muscles within the first 6 months being 70 per cent and within the first year almost 90 per cent (Figure 1).

Skinhøj found that of 702 grade 0 muscles in his study 70 per cent were still grade 0 at follow up 3 years later and that only 12 per cent were of functional value.

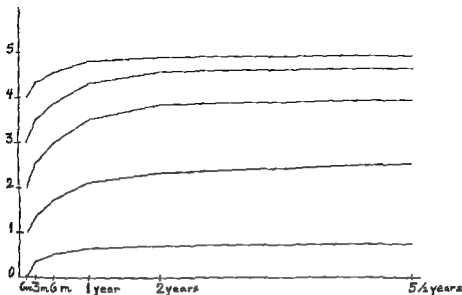


Figure 1 Muscle recovery through 5½ years for all muscles of grade 0 1 2 3 and 4 from all 750 patients

In the present material 80 per cent of 919 grade 0 muscles remained grade 0 or 1 at the end of 5½ years while 10 per cent had attained functional value

Out of the 682 muscles which were still grade II three months after the onset of polio 95 per cent remained grade 0 or 1 at the end of 5½ years and only 2.5 per cent were of functional value

Correspondingly of the 600 grade II muscles at 6 months 97 per cent still remained grade 0 or 1 at the end of 5½ years and only 1/2 per cent had attained functional value

In other words a muscle which remains grade 0 three months after the onset of polio has a very poor prognosis

The prospects for grade 1 and 2 muscles in the present material were as follows

Of 1483 grade 1 muscles 50 per cent had gained functional value at the end of 5½ years

Of 1643 grade 2 muscles 88 per cent had gained functional value at the end of 5½ years

Slonhoj reported that of 575 grade 1 and 2 muscles 56 per cent were of functional value at the end of 3 years

A comparison of muscle recovery in children and adults showed

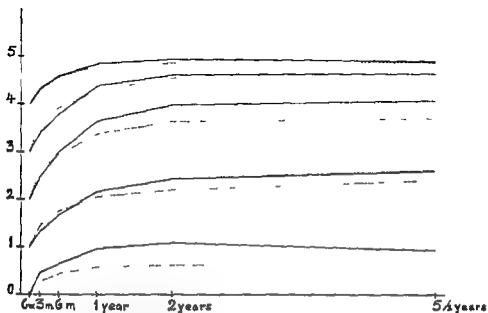


Figure 2 Muscle recovery through 5 1/2 years for all muscles of grade 0 1 2 3 and 4 In patients over 15 years of age solid line In patients aged 4-15 years dotted line

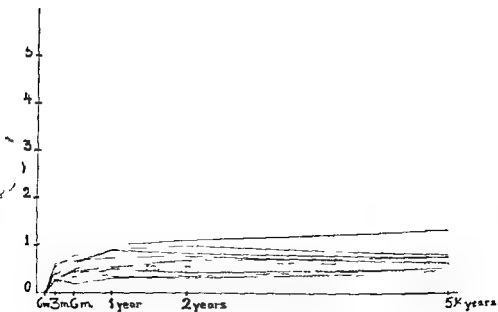


Figure 3 Muscle recovery through 5 1/2 years for all grade 0 muscles in the lower limbs Muscles above the knee solid line Muscles below the knee dotted line

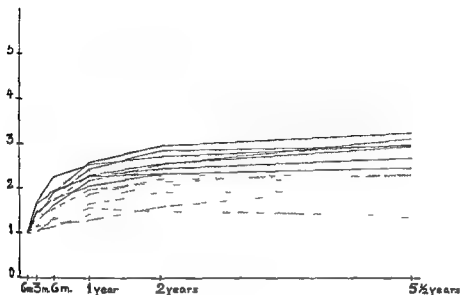


Figure 4 Muscle recovery through 5½ years for all grade 1 muscles in the lower limbs. Muscles above the knee solid line. Muscles below the knee dotted line.

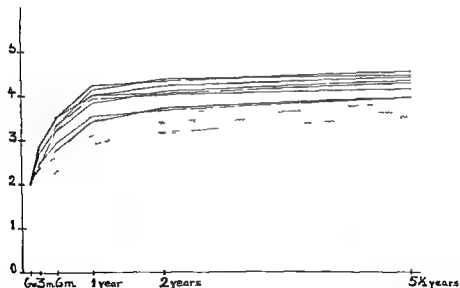


Figure 5 Muscle recovery through 5½ years for all grade 2 muscles in the lower limbs. Muscles above the knee solid line. Muscles below the knee dotted line.

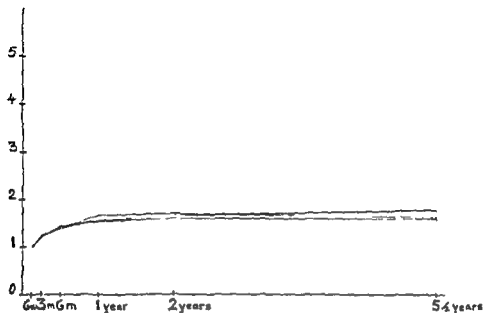


Figure 6 Muscle recovery through 5 1/2 years for all grade 1 abdominal muscles solid line and all grade 1 back muscles dotted line

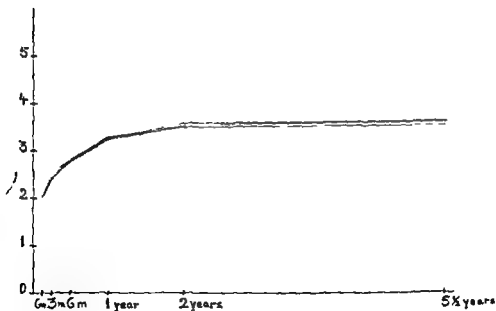


Figure 7 Muscle recovery through 5 1/2 years for all grade II abdominal muscles solid line and all grade II back muscles dotted line

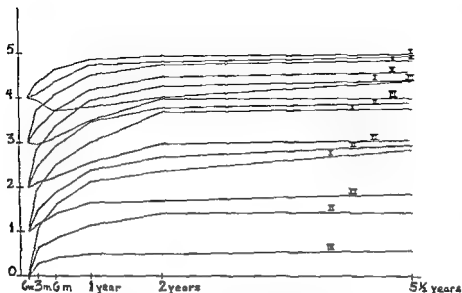


Figure 8. Muscle recovery through 5½ years for all grade 0 1 2 3 and 4 muscles from all 240 patients divided into three sub-groups according to their site i.e. in limbs having degree I II or III total paralysis

hardly any definite difference in the present material (Figure 2). A finding of better regeneration in children by previous workers may be due to the inclusion of children under 4 years of age in whom the assessment of muscle function must be fairly uncertain.

In respect to the ability of the individual muscles to recover the proximal groups of muscles in the lower limbs seemed to have a somewhat better prognosis than the peripheral ones. This is in keeping with previous findings (Figures 3, 4 and 5). In the upper limbs it has not been possible to demonstrate any definite difference between proximal and peripheral muscles apart from the poor outlook for the *opponens pollicis*. The prognosis for abdominal muscles was poor for back muscles fairly good (Figures 6 and 7). *Skinhøj's* material showed the same findings for the *opponens* and abdominal muscles.

A factor which appears to be of decisive importance to the prognosis of the individual muscle is the degree of paralysis in adjacent muscles i.e. the total functional defect in the limb. In the event of severe paralysis of two or more functionally important muscles we classified the degree of paralysis in the limb as III i.e. a severe functional loss in the limb concerned. In these cases there are invariably severe widespread

paralyses With a functional defect of moderate degree the limb was listed as having a degree II paralysis and with slight functional reduction it was listed as degree I

Table 1

Muscle power	Time of test	Difference found in the course of the curves showing muscle recovery for all grade 0 I II 3 and 4 muscles in limbs having		
		I-II paralysis	I-III paralysis	II III paralysis
0	3 months	significant	significant	significant
	6 months		"	"
	1 year		"	"
	2 years		"	"
1	3 months	significant	significant	significant
	6 months		"	"
	1 year			"
	2 years		"	"
2	3 months	significant	significant	significant
	6 months	"		"
	1 year		"	"
	2 years			"
3	3 months	significant	significant	significant
	6 months		"	"
	1 year			"
	2 years	"		"
4	3 months	significant	significant	not significant
	6 months		"	" "
	1 year	"	"	" "
	2 years	"		" "

If the muscles found at the first test to be of the same degree of paralysis are divided into 3 sub groups according to their site—I II or III in a limb with degree I II or III total paralysis—they show a decisive difference in their tendency to recover. Muscles in a severely paralysed limb show very little improvement. On the other hand muscles in a slightly paralysed limb have a very favourable prognosis (Figure 5). This factor is of such decisive importance that even long lasting systematic training does not essentially alter the course. This seems important in deciding how long a systematic training should reasonably be continued. The difference between the prognosis for muscles in

*Table 2 Frequency of affection of lower limb muscles
Muscles listed according to frequency of involvement*

Sharrard (147 patients)		Present material (240 patients)	
Quadriceps	184	Tibialis anterior	200
Gluteus medius	143	Gluteus medius	184
Internal popliteal	168	Iliopsoas	183
Biceps femoris	164	Tibialis posterior	146
Adductors	162	Biceps femoris	174
Iliopsoas	159	Tensor fasciae latae	171
Tibialis anterior	152	Adductors	164
Tensor fasciae latae	149	Quadriceps	167
Gluteus maximus	142	Internal popliteal	153
Tibialis posterior	140	Extensor digitorum longus	147
Flexor hallucis longus	133	Gluteus maximus	132
Flexor digitorum longus	130	Extensor hallucis longus	128
Extensor digitorum longus	130	Triceps surae	120
Triceps surae	129	Peronei	109
Peronei	126	Flexor hallucis longus	106
Extensor hallucis longus	125	Flexor digitorum longus	100

Table 3 Incidence of complete and partial paralysis of lower limb muscles (after Sharrard 1955) Muscles listed according to frequency of complete paralysis Ratio partial to complete paralysis Approximate length of motor cell column in the cord

	Number completely paralysed	Number partially paralysed	Ratio partial to complete paralysis	Approximate length of motor cell column in the cord
Tibialis anterior	103	49	0.47	8 mm
Tibialis posterior	89	51	0.57	8 mm
Flexor digitorum longus	85	45	0.52	8 mm
Flexor hallucis longus	84	49	0.58	8 mm
Extensor hallucis longus	66	59	0.89	9 mm
Extensor digitorum longus	63	67	1.06	10 mm
Peronei	60	66	1.10	10 mm
Triceps surae	57	72	1.26	14 mm
Biceps femoris	51	110	2.03	14 mm
Gluteus medius	47	131	2.78	16 mm
Quadriceps	46	138	3.00	22 mm
Internal popliteal	43	15	2.90	20 mm
Tensor fasciae latae	33	111	2.97	16 mm
Adductors	36	127	3.50	27 mm
Iliopsoas	34	15	3.67	22 mm
Gluteus maximus	33	109	3.30	17 mm

limbs with I, II and III paralysis proved with a single exception to be statistically significant (Table 1).

Several workers including Lovett, Skinhof and Sharrard, have found that while the absolute number of affected muscles was greater for the proximal than for the distal lower limb muscles (Table 2) the number of completely paralysed muscles was greater in the lower leg and foot. On this basis Sharrard calculated a coefficient partial/complete paralysis for each muscle in the lower limbs and found this coefficient to be lowest in the distal muscles. A similar analysis of our material showed a certain agreement (Tables 3 and 4). The great difference in the level of coefficients in Sharrard's material and ours is probably due to a difference in the severity of the epidemics and perhaps also to a difference in patient selection.

Table 4. Present material listed in the same way as Sharrard's (Table 2).

	Number completely paralysed	Number partially paralysed	Ratio partial to complete paralysis	Approximate length of motor cell column in the cord
Tibialis anterior	91	109	1.20	8 mm
Tibialis posterior	52	124	2.39	8 mm
Extensor hallucis	41	87	2.12	9 mm
Peronei	40	69	1.72	10 mm
Quadriceps	38	121	3.26	12 mm
Extensor digitorum longus	37	103	2.80	10 mm
Internal popliteal	28	115	4.14	20 mm
Adductors	29	136	4.69	12 mm
Elliopsoas	27	156	5.77	23 mm
Biceps	27	148	5.69	14 mm
Flexor hallucis longus	25	81	3.24	8 mm
Flexor digitorum longus	23	77	3.35	8 mm
Triceps surae	23	97	4.22	14 mm
Gluteus medius	16	168	10.50	16 mm
Gluteus maximus	15	117	7.80	17 mm
Tensor fasciae latae	12	159	13.25	16 mm

In the same way Sharrard found that the average number of completely or partly paralysed muscles supplied by a given spinal segment was largest for the I, 1, 1, 2 and 1, 3 segments falling below this level.

* Calculated by Erling Detsau.

while the average number of completely paralysed muscles supplied by a given segment was almost the same from L 4 downwards. About the same applies to our material (Table 5).

Table 5. Average number of partially or completely (2nd column) and completely (3rd column) paralysed muscles innervated from each cord segment. Present material.

	Average number of partially or completely paralysed muscles	Average number of completely paralysed muscles
L 1	183	27
L 2	169	31
L 3	169	31
L 4	177	38
L 5	149	34
S 1	143	35
S 2	137	31

Similarly Sharrard in his very interesting pathological studies on the spinal cords from 7 polio patients found a characteristic difference in the length of the columns of anterior horn cells which form the nerve nuclei of the individual muscles. He demonstrated that while the proximal muscles in the hip region and in the thigh are supplied by relatively long cell columns, the cell columns for the muscles on the lower leg and foot are considerably shorter. This he took to explain the previously mentioned fact that the total number of completely or partly paralysed muscles is greater for the proximal muscles while the number of completely paralysed muscles is larger as far as the distal muscles are concerned (Tables 3 and 4).

SUMMARY

Muscle recovery through 5½ years after the onset of poliomyelitis was assessed by regular testing of muscle power in 240 patients: 117 adults and 123 children over 4 years of age. The assessment was based upon manual testing of muscle power 6 weeks, 3, 6 and 12 months, 2 and 5½ years after the onset of polio. It was found that about 50 per cent of muscle recovery took place within the first 6 months, a total of about 75 per cent within the first year, and a total of 90-95 per cent within the first 2 years. As far as grade 0 muscles were concerned, however,

these findings were 70 per cent, 90 per cent and 95 per cent respectively. A finding of great importance was that muscles which were grade 0 three months after the onset of polio had a very poor prognosis 95 per cent remaining grade 0 or 1. As far as the grade 1 or 2 muscles were concerned 50 per cent and 88 per cent acquired functional value in 5½ years.

In this material there did not seem to be any definite difference between muscle recovery in adults and children.

The prognosis seems somewhat better for proximal than for distal muscles in the lower limbs, poor for the opponens pollicis and poor for the abdominal muscles.

A certain conformity was found on comparison with *Stinshøj's* and with *Sharrard's* findings. For instance the absolute number of completely or partly paralysed muscles was found to be largest for the proximal lower limb muscles while the largest number of totally paralysed muscles was found in the lower leg and foot.

The ability for recovery in a muscle of any paralytic grade depends largely upon the degree of total paralysis, i.e. the functional defect of the limb concerned. If the total defect is severe the prognosis is poor. If it is mild the prognosis is favourable.

RESUME

La guérison des muscles a été étudiée pendant 5 ans et demi après une attaque de poliomyélite par le test de la force musculaire chez 2 malades, 117 adultes et 123 enfants de plus de 4 ans. L'observation a été basée sur le test manuel de la force des muscles 6 semaines, 3, 6 et 12 mois, 2 et 5 ans ½ après l'attaque de polio. Il a été constaté que pour environ 50 pour cent des cas la guérison des muscles a lieu dans les premiers six mois, pour environ 75 pour cent durant la première année et pour un total de 90 à 95 pour cent durant les deux premières années. En ce qui concerne les muscles classés 0 ces données sont cependant de 70 pour cent, 90 pour cent et 95 pour cent respectivement. Une trouvaille de grande importance est que les muscles classés 0 trois mois après l'attaque de polio ont un pronostic très défavorable, 95 pour cent restent au degré 0 ou 1. En ce qui concerne les muscles de degré 1 ou 2, 50 pour cent et 88 pour cent acquièrent une valeur fonctionnelle dans l'espace de 5 ans et demi.

Dans ce matériel d'observation il ne semble pas exister de différence nette entre la guérison des muscles chez les adultes et les enfants.

Le pronostic semble être un peu meilleur pour les muscles de la partie proximale des extrémités inférieures que pour ceux de la partie distale. Il est mauvais pour l'opposant du pouce et pour les muscles dominants.

Il a été trouvé une certaine conformité en effectuant une comparaison avec les trouvailles de *Skinhøj* et de *Sharrard*. C'est ainsi que le nombre absolu des muscles entièrement ou partiellement paralysés est plus élevé pour les muscles de la partie proximale des extrémités inférieures, alors que c'est dans la partie inférieure de la jambe et dans le pied qu'on a trouvé le plus grand nombre de muscles totalement paralysés.

La faculté de guérison d'un muscle dépend largement du degré de la paralysie générale ou de la défectuosité fonctionnelle du membre dont il s'agit. Le pronostic est défavorable si l'état général est mauvais, alors que le pronostic est favorable si l'état général n'est que légèrement défectueux.

ZUSAMMENFASSUNG

Muskelerholung während $5\frac{1}{2}$ Jahren nach dem Beginn von Poliomyelitis wurde mittels regelmässiger Prüfung der Muskelkraft bei 240 Patienten: 117 Erwachsenen und 123 Kindern über 4 Jahre festgestellt. Die Schätzung hatte zur Grundlage die manuelle Prüfung der Muskelkraft 6 Wochen, 3, 6 und 12 Monate, 2 und $5\frac{1}{2}$ Jahre nach dem Beginn der Poliomyelitis. Es wurde gefunden, dass ungefähr 50 Prozent der Muskelwiederherstellung während der ersten 6 Monate stattfindet, ein Gesamtwert von ungefähr 75 Prozent innerhalb des ersten Jahres und ein Gesamtbetrag von 90–95 Prozent innerhalb der ersten 2 Jahre. Insofern als es die Grad 0 Muskeln betraf, waren diese Befunde jedoch 70 Prozent, 90 Prozent und 95 Prozent beziehungsweise. Ein Befund von grosser Wichtigkeit war, dass Muskeln, die drei Monate nach dem Beginn der Polio Grad 0 waren, eine sehr schlechte Prognose hatten, in dem 95 Prozent Grad 0 oder 1 verblieben. So weit es sich um Grad 1 und 2 Muskeln handelte, erwarben 50 Prozent und 88 Prozent einen funktionellen Wert im Verlaufe von $5\frac{1}{2}$ Jahren.

In diesem Materiale schien kein sicherer Unterschied zwischen der Muskelerholung von Erwachsenen und Kindern zu bestehen.

Die Prognose scheint etwas besser für die proximalen als für distalen Muskeln der unteren Extremität zu sein, schlecht für den Opponens pollicis und die Bauchmuskeln.

Eine gewisse Übereinstimmung mit den Befunden von Skinhøj und Sharrard wurde gefunden. Zum Beispiel die absolute Zahl von vollständig oder teilweise gelähmten Muskeln wurde am grössten für die proximalen Muskeln der unteren Gliedmaasse gefunden während die grösste Anzahl von vollständig gelähmten Muskeln im Unterschenkel und Fuss gefunden wurde.

Die Erholungsfähigkeit eines Muskels von irgendeinem Lähmungsgrad hängt weitläufig von dem Grade der totalen Lähmung ab d. h. von dem funktionellen Defekt der betroffenen Gliedmaasse. Wenn der totale Defekt schwer ist wird die Prognose schlecht sein ist er mild dann ist die Prognose günstiger.

REFERENCES

- Lolett H W (1915) The Treatment of Infantile Paralysis *Amer med Ass* 61 2-118
- Lolett H W (1917) Fatigue and Exercise in the Treatment of Infantile Paralysis. A Study of One Thousand Eight Hundred and Thirty Six Cases *Amer med Ass* 69 169
- Seddon H J (1930) Poliomyelitis Part II—Treatment of Poliomyelitis In *British Surgical Practice Surgical Progress 1931* p 167 London Hutterworth & Co (Publishers) Ltd
- Sharrard W J (1931) Muscle Recovery in Poliomyelitis *J Bone Jt Surg* 37 B 53-79
- Sharrard W J (1935) The Distribution of the Permanent Paralysis in the Lower Limb in Poliomyelitis *J Bone Jt Surg* 37 B 340-509
- Skinhøj Erik (1949) Some Problems of Acute Anterior Poliomyelitis and its Sequelae Thesis

